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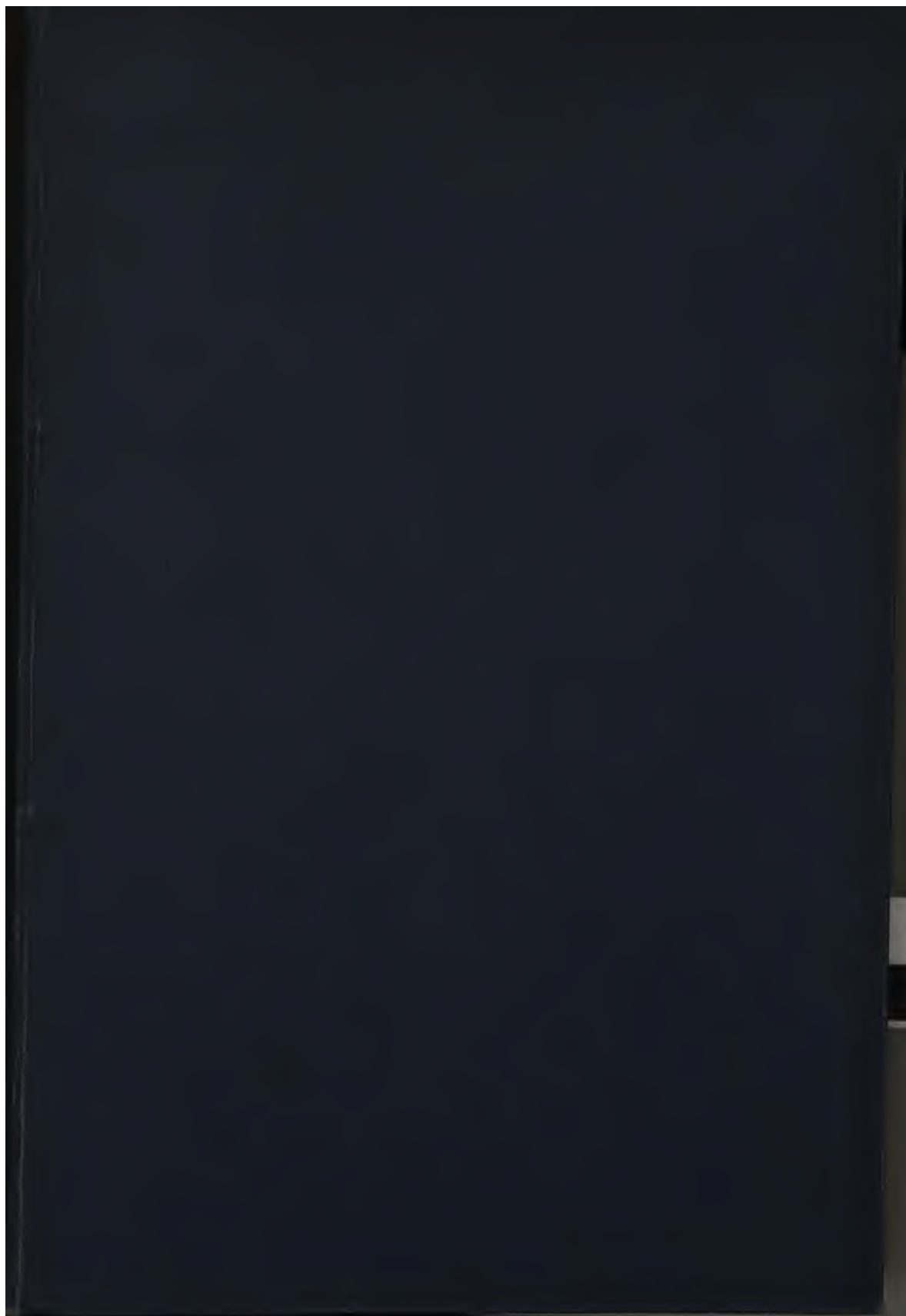
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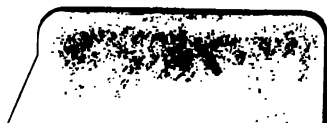
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OF THE
BRITISH GRAPTOLITIDÆ

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A MONOGRAPH
OF THE
BRITISH GRAPTOLITIDÆ

BY

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PREFACE.

THE present work is the first instalment of a detailed Monograph of the Graptolites of Britain, for which I have been engaged in collecting materials for some years. It is intended to serve as an Introduction to the study of the *Graptolitidæ* generally; and I have, therefore, where necessary, introduced any important considerations which at present are to be derived from foreign sources alone.

The work is, in the main, based upon my own private collection, which, though very extensive, necessarily exhibits more fulness in some departments than in others, whilst there are points in which I have had to rely entirely upon the observations of others. In this connection I must not omit to record the great obligations which I am under to the published writings of Professor James Hall and M. Joachim Barrande.

The nature of the subject is such that I do not feel called upon to apologise for the hesitating and doubtful tone in which I have felt compelled to speak of many points of interest and importance. Nor do I see any reason to shrink from the avowal that I have in some instances seen fit to modify or abandon views

which I formerly expressed, as the result either of the criticisms of others or of my own more mature observations.

Many of the illustrations are original, and are drawn from specimens in my own collection. The source of others is acknowledged in the text; and in this connection I must express my thanks to Sir William Logan, F.R.S., who most liberally placed at my disposal all the engravings which were used by Professor Hall in his Monograph of the Graptolites of the Quebec Group (Decade II. of the Geological Survey of Canada).

The remaining portions of the work will treat of the British species of Graptolites in detail, and will be successively issued as my leisure will permit.

TORONTO, *November 17, 1871.*

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PART I.

GENERAL INTRODUCTION

BRITISH GRAPTOLITES.

CHAPTER I.

HISTORICAL NOTICES.

THE earliest notice of Graptolites is probably to be found in the writings of Bromel, who, in describing the fossils of Sweden in 1727, alludes to some as resembling the fossil leaves of grasses.

The name *Graptolithus* (Gr. *grapho*, I write ; *lithos*, stone) appears for the first time in the first edition of the 'Systema Naturæ' of Linnæus. The name, however, was originally applied by Linnæus to certain natural objects, most of which were certainly not Graptolites, and which he himself did not believe to be true fossils at all. In the twelfth edition of the 'Systema' (Stockholm, 1768) there is to be found a description of a fossil termed by Linnæus *Graptolithus scalaris*, the exact nature of which has formed the subject of some controversy. This so-called *Graptolithus scalaris* was originally described by Linnæus, and figured in his 'Scanian Travels' (Skanska Resa), which were published in 1751. I have not had the opportunity of reproducing the original figure of Linnæus, but I subjoin a copy of the fac-simile of the same given by Geinitz (Die Graptolithen, vi. fig. 20), which will be accurate enough for all practical purposes (see fig. 1).

From this figure it will be seen that two wholly dissimilar

objects are represented in this primitive sketch. The two spiral bodies are unquestionably Graptolites, and may very possibly be referable to the base of the species now known as *G. Sedgwickii*, Portl. The straight body, however ("lineam striasque transversas referens"), is the original *G. scalaris*; and a rather unfruitful controversy has been carried on as to its exact nature. The question, however, is not wholly unimportant, as changes in our nomenclature have been advocated on the basis of the supposed nature of this figure.

Fig. 1.

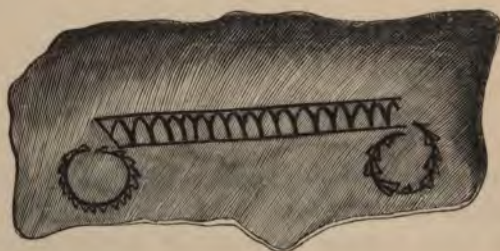


Figure of *Graptolithus scalaris*, Linn., after Linnæus. From 'Skanska Resa, p. 147. Copied from Geinitz.

By Wahlenberg, Geinitz, and Barrande, *G. scalaris*, Linn., is regarded as a unicellular or monoprionidian Graptolite (viz., *G. sagittarius*) compressed in a direction rectangular to the cellules, so that the apertures of the cellules are shown running across the stipe transversely. Upon this view the term "scalariform" was introduced, to indicate specimens of any Graptolite compressed in this peculiar manner. By Hall (Grapt. Quebec Group, p. 111) *G. scalaris* is looked upon as the type of a double-celled or diprionidian genus (*Climacograpsus*), of which the typical form is the well-known *Prionotus* (*Diplograpsus*) *teretiusculus* of Hisinger. This view of Hall's is adopted by Mr W. Carruthers (Intellectual Observer, May 1867; Geol. Mag. v. p. 131), who further adopts Hall's suggestion that the familiar species, *C. teretiusculus*, His., sp., should be named *C. scalaris*.

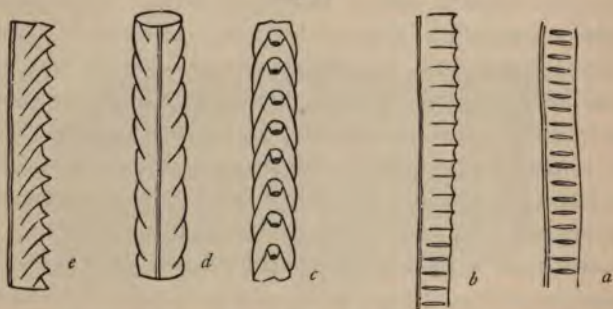
As regards my own views upon this subject, I should be

rather disposed to doubt that the original figure of *G. scalaris* was taken from any Graptolite at all. Admitting, however, that it is a Graptolite, it is quite certain that it is impossible at the present day to decide what species it was originally meant for. I am also perfectly satisfied that it is wholly impossible, as things stand, to determine whether *G. scalaris* was intended for a monoprionidian or a diprionidian form; and no grounds can be found for the substitution of *scalaris* for *teretiusculus*, unless it can be demonstrated that the original *G. scalaris* was a bicellular form. The promoters of this substitution appear to have proceeded upon the erroneous belief that unicellular Graptolites do not exhibit "scalariform" views. On the contrary, numerous instances occur in which monoprionidian Graptolites exhibit "scalariform" impressions which are absolutely undistinguishable from those impressions of any *Climacograpsus* in which no more than the apertures of a single row of cellules is exhibited. This is shown most satisfactorily by the occurrence of specimens of monoprionidian Graptolites which exhibit their ordinary characters over part of their course, but are then twisted so as to exhibit a "scalariform" view. It is also most satisfactorily proved by the occurrence of numerous scalariform impressions in rocks (such as the Coniston Grits of the north of England) in which the most careful search has hitherto failed to reveal a single double-celled Graptolite. I subjoin a cut (fig. 2) showing the phenomena above mentioned, as they occur in *G. colonus*, Barr., and *G. priodon*, Bronn—all the specimens figured having been obtained from deposits which have hitherto yielded no examples of either *Diplograpsus* or *Climacograpsus*.

If, then, the original *G. scalaris*, Linn., be a Graptolite, it is, to say the least of it, quite as likely to be the scalariform impression of a monoprionidian species as of a double-celled form. I am, therefore, decidedly of the opinion that there are no grounds for accepting the change proposed by Hall and followed by Carruthers—a change which would substitute for a well-recognised and long-current form an altogether dubious and undeterminable species.

The only other noticeable Graptolite described by Linnæus is one the name of which has since been almost universally transferred to a very common and well-marked species, for which the original title of *Graptolithus sagittarius* has been generally retained. By Barrande (Grapt. de Bohême, p. 34) *Graptolithus sagittarius*, Linn., is regarded as identical with *G. scalaris*, Linn., and it is looked upon as "the true historical prototype of the genus *Graptolithus*, and of the whole

Fig. 2.



- a*, Scalariform impression of *G. colonus*, Barr., from the Coniston Grits near Sedbergh. *b*, Another specimen of the same, from the same locality, in which the frond is slightly twisted, so as to yield a completely scalariform impression in its lower portion and a semi-scalariform view in its upper portion. *c*, Scalariform view of a fragment of *G. priodon*, Bronn, preserved in relief, from the Coniston Flags of Broughton Moor. *d*, Back view of the frond of *G. priodon*, Bronn, showing the solid axis and cell-partitions; from a specimen from the base of the Coniston Flags, west side of Long Sleddale. *e*, Ordinary lateral view of a fragment of *G. colonus*, Barr., showing the cell-denticles; from the Coniston Grits near Sedbergh. All considerably enlarged.

family of the Graptolites." By Geinitz (Die Graptoliten, p. 1) *G. sagittarius*, Linn., is looked upon as being probably founded upon some double-celled form, such as *Diplograpsus* (*Graptolithus*) *pristis*, His., or *Diplograpsus folium*, His. By Mr Carruthers (Geol. Mag., v. p. 71) *G. sagittarius*, Linn., is said to have been founded upon a drawing of a fragment of a *Lepidodendron* in Volkmann's 'Silesia Subterranea' (1720). This drawing I have had no opportunity of examining, but Mr Carruthers is doubtless correct in his opinion; and there can, at any rate, be no doubt that the description of Linnæus is inapplicable to any recognised

species of Graptolite. The name of *Graptolithus sagittarius* has, however, been applied by Hisinger, Barrande, Geinitz, Murchison, Salter, Harkness, and others, to one very common and well-defined monopronidian Graptolite. Since the name given by Linnæus can never in future be applied to any other Graptolite, and since it has obtained such a general currency in the classical writings upon the subject, though not in the sense in which it was originally used, I prefer retaining it for the species now universally known under this name. I regret, therefore, that I am unable to concur in the propriety of the change recently advocated by Mr Carruthers, who proposes to substitute for *Graptolithus sagittarius* the name of *G. Hisingeri* (Geol. Mag., v. p. 71).

Before proceeding to give a summary of the literature of the Graptolites in times later than those of Linnæus, I may say a few words as to the use of the term *Graptolithus* or *Graptolites* in its present restricted application to one genus of the family *Graptolitidæ*. In the 'Systema Naturæ,' Linnæus originally employed the term *Graptolithus*; and, as a matter of course, this is the correct spelling from an etymological point of view. In the 'Scanian Travels,' Linnæus had altered the name to *Graptolitus*. In the 'Silurian System' (1839), Sir Roderick Murchison slightly altered the name to *Graptolites*, and this alteration has been very generally followed by British palæontologists. Professor Hall, however, the great American authority upon this subject, constantly employs the original *Graptolithus*, and in England Mr Carruthers has also reverted to this mode of spelling. Whilst the etymological correctness of *Graptolithus* is unquestionable, there really does not appear to be any strong ground for retaining the *h*, and thus departing from the exceedingly common palæontological custom by which the termination *lithus* is changed into *lites*. Scores of examples of this habit might be adduced—such as *Heliolites*, *Alveolites*, *Serpulites*, *Cornulites*, *Nidulites*, *Retiolites*, *Cyrtolites*, &c. &c. All these, and many others, ought to end in *lithus*, if strict etymological accuracy is to be insisted on. No objection, however, is ever made to the ordinary habit in these and many similar cases ;

and it seems to me that no special reason exists in this case rendering the use of *Graptolites* inappropriate. It is a matter of small moment; but I shall, in what follows, employ the term *Graptolites*, if only upon the ground that it appears in such a classical work as the 'Silurian System,' and has acquired a general currency in the writings of Portlock, M'Coy, Salter, and Harkness.

In the following historical notice of Graptolites subsequent to the time of Linnæus, I have relied chiefly upon the bibliographical lists given by Barrande (*Grapt. de Bohême*, p. 33), and Hall (*Grapt. Quebec Group*, p. 59)—the former taking us up to the year 1849, the latter to the year 1863. The list is necessarily imperfect, partly from the impossibility of discovering all that has been written upon this subject, and partly because many of the original works cannot be obtained here for reference. I have, however, added to Hall's list all the more important papers which have appeared subsequent to 1863:—

HISTORICAL NOTICE OF GRAPTOLITES.

1821. Wahlenberg endeavoured to establish the view that the Graptolites were very slender *Orthocerata* (*Nova Acta. Soc. Sci. Upsal*, viii. pp. 92, 93). This view was especially based on examples preserved in relief in the Scanian schists.

1822. Schlotheim, adopting Wahlenberg's views as to the nature of Graptolites, figured and described a species under the name of *Orthoceratites serratus* (*Petrefactenkunde*, p. 56, pl. VIII. fig. 3).

1828. Ad. Brongniart described two species of Graptolites from the Transition formation at Point Lévis, near Quebec, in Canada (Quebec Group), as furoids, under the names of *Furoides dentatus* and *F. serra* (*Histoire des Végétaux Fossiles*, pp. 70, 71, pl. VI. figs. 7-12).

1829 (1831?). Friedrich Holl republished the description of *Orthoceratites serratus* of Schlotheim (*Handbuch der Petrefacten*, ii. p. 234).

18—? Professor Nilsson recognised the affinity of the Graptolites to the Polypes, and referred them to the family

of the Ceratophydians. He further proposed for them the name of *Priodon*, which had been already applied by Cuvier to a genus of fishes (Mem. Physiographic. Soc. of Lund.—See Beck's Note in Murchison's 'Silurian System,' p. 696).

1835. Professor Bronn adopts Nilsson's views as to the nature of Graptolites, and substituted for *Priodon* the name of *Lomatoceras*, which had previously been given to an insect. He names and figures here the cosmopolitan species *Graptolites* (*Lomatoceras*) *priodon* (Lethæa Geognostica, i. p. 55).

1837. Hisinger described five species of Graptolites from the Silurian Rocks of Sweden, adopting the generic name of *Prionotus*, formerly created by Professor Nilsson in place of *Priodon*. Amongst these are the two Linnæan species, *P. sagittarius* and *P. scalaris*, and three new forms, *P. pristis*, *P. folium*, and *P. convolutus* (Lethæa Suecica, p. 113, pl. 35). In the second supplement to this work (1840) he adds two other species, *P. geminus* and *P. teretiusculus* (Supp. ii. p. 5, pl. 38).

1839. Sir Roderick Murchison described and figured in his 'Silurian System' three species of Graptolites, *G. Ludensis*, *G. Murchisoni*, and *G. foliaceus* (Sil. Syst., p. 695). Sir Roderick Murchison expresses here the opinion that Graptolites show most affinity with the living *Pennatulidæ*, in accordance with the views expressed in a letter to him by Dr Beck. The importance of the Graptolites as Silurian fossils is also recognised here for the first time.

1840. Professor Eichwald mentions, without figuring, a form from the Silurian Rocks of Esthonia, under the name of *Lomatoceras distichum* (Sil. Syst. in Esthland, p. 101).

1840. Professor Quenstedt endeavoured to prove that the Graptolites were *Foraminifera*, at that time referred to the *Cephalopoda*; thus approximating closely to the view originally put forth by Wahlenberg (Leonhard's and Bronn's Jahrbuch, pp. 274-276).

1842. Alcide d'Orbigny discovered the first Graptolite in South America, in Bolivia, and he named it *G. dentatus* (Voyage dans l'Amérique Méridionale, iii., pl. II. figs. 1, 2).

1842. Professor Geinitz described and figured five species of Graptolites under the names of *G. foliaceus*, Murch., *G.*

priodon, Bronn, *G. Ludensis*, Murch., *G. serratus*, Schloth., *G. scalaris*, Linn., and *G. spiralis*, Gein. He supported Wahlenberg's view that the Graptolites were referable to the *Cephalopoda*. (Leonhard's and Bronn's Jahrbuch, 1842, p. 697-701.)

1842. Vanuxem identified a Graptolite of the Utica Slate with the *Fucoides dentatus* of Brongniart. (Geol. Rep. 3d Dist. N. Y., p. 57, fig. 2.)

1843. General Portlock, in his Geological Report, discussed the nature of Graptolites, and was the first to recognise their now generally admitted affinity to the Hydroid Zoophytes, regarding them as most nearly allied to the modern *Sertularia* and *Plumularia*. He also expressed an opinion, which is gradually gaining more and more ground, that the Graptolites should probably be referred to more than one order. The forms described by Portlock are mentioned under nine distinct species:—*G. Sedgwickii*, *G. distans*, *G. tenuis*, Portl.; *G. convolutus*, *G. sagittarius*, *G. pristis*, and *G. folium*, Hisinger; *G. scalaris*, Linn.; and *G. foliaceus*, Lonsd. The fossils described by Portlock as *Gorgonia* belong probably to the more modern genera *Dictyonema* and *Callograpsus* (or *Dendrograpsus*). (Geol. Rep. on Londonderry, Tyrone, and Fermanagh, pp. 317-321, pls. XIX. and XX.)

1843. W. W. Mather and E. Emmons recognised *Graptolithus dentatus* as characterising the Utica Slate. (Geol. Rep. 1st Dist. N. Y., p. 390, and Geol. Rep. 2d Dist. N. Y., p. 279.)

1843. Professor James Hall described *Graptolithus Clintonensis* from the Clinton Group in the Upper Silurian Series of North America. (Geol. Rep. 4th Dist. N. Y., p. 72, fig. 12.)

1845. Sir Roderick Murchison, De Verneuil, and Count Keyserling enumerated *G. sagittarius*, His., and *G. distichus*, Eichw., as characterising the Silurian formations of Russia. (Geol. of Russia and the Ural Mts., ii. p. 382.)

1846. Professor Geinitz repeats the opinion which he had formerly expressed in 1842 as to the Graptolites being referable to the *Cephalopoda*, and divides the group into two sections, comprising respectively the straight and spiral forms.

In the first section he describes four species:—*G. foliaceus*, Murch., *G. priodon*, Bronn, *G. sagittarius*, Linn., and *G. serratus*, Schloth. In the second section he describes *G. convolutus*, His.

1846. Mr E. Emmons published *Fucoides simplex* (= *Graptolithus secalinus*, Hall), from the roofing-slates of Hoosic. (Nat. Hist. N. York, Agriculture, i., pl. XVII. fig. 1.)

1847. Professor James Hall described and figured fifteen species of Graptolites, mostly new, from the Lower Silurian Series of North America, placing them amongst the Zoophytes. The species described are:—*Graptolithus pristis*, His., *G. secalinus*, Hall, *G. mucronatus*, Hall, *G. bicornis*, Hall, *G. ramosus*, Hall, *G. scalaris*, Linn., *G. sagittarius*, His., *G. tenuis*, Portlock, *G. sextans*, Hall, *G. furcatus*, Hall, *G. serratulus*, Hall, *G. gracilis*, Hall, and *G. (?) lævis*, Hall. (Palæontology of N. York, i., pls. 72, 73, 74.)

1848. The Rev. Professor Sedgwick announced the discovery of *G. sagittarius*, His., and *G. latus*, M'Coy, in the Skiddaw Slates of the North of England. (Quart. Journ. Geol. Soc., iv. p. 223.)

1848. Mr Salter described *G. folium*, *G. pristis*, His., *G. pristis*, var. *foliaceus*, Portlock, *G. ramosus*, Hall, *G. tænia*, Sowerby and Salt., *G. tenuis*, Portl. (?), and *G. sextans*, Hall, from the Lower Silurian Slates of Loch Ryan and other localities in Wigtownshire. (Quart. Journ. Geol. Soc., v. pp. 15-17, pl. I. figs. 5-10.)

1848. Professor Phillips enumerated *G. Ludensis*, Murch., *G. Murchisoni*, Beck, and three other species from the Silurian Rocks of Builth, Llandeilo, and Haverford-west. (Mem. Geol. Survey, ii., part I. p. 308.)

1849. Professor Bronn placed the Graptolites near the *Pennatulidæ*, following Beck, and divided them into *species spirales*, *rectæ*, *ancipites*, and *gemellæ*. (Index palæontologicus, in Geschichte der Natur, iii., part II. p. 149.)

1849. Professor James Nicol described *G. Ludensis*, Murch., *G. convolutus*, His., *G. latus*, n. sp. and *G. Griestonensis*, n. sp. from the Lower Silurian Rocks of the south of Scotland. (Quart. Journ. Geol. Soc., vi. pp. 63, 64.)

1849. Professor James Hall stated the occurrence of twenty species of Graptolites—some not at that time described—in the Lower Silurian Rocks of North America. Besides these were two other forms from the Clinton Group. (Proc. American Assoc. for the Advancement of Science, 1849, p. 351.)

1850. M. Barrande published a Memoir upon the Graptolites of Bohemia. He established the genus *Rastrites* with four species and the genus *Gladiolites* (*Retiolites*) with one species. The remaining species he retained in the genus *Graptolithus*, but subdivided into two sections—*Monoprion* and *Diprion*—including respectively the forms with cellules on one side and those with cellules on both sides. The following forms are described in this important and valuable Memoir—*G. priodon*, Bronn, *G. Bohemicus*, Barr., *G. tectus*, Barr., *G. colonus*, Barr., *G. nuntius*, Barr., *G. Ræmeri*, Barr., *G. Halli*, Barr., *G. Nilssoni*, Barr., *G. palmeus*, Barr., *G. ovatus*, Barr., *G. spiralis*, Gein., *G. Becki*, Barr., *G. testis*, Barr., *G. turriculatus*, Barr., *G. Proteus*, Barr., *G. Chimæra*, Barr., *Rastrites fugax*, Barr., *R. Linnæi*, Barr., *R. gemmatus*, Barr., *R. peregrinus*, Barr., and *Gladiolites* (*Retiolites*) *Geinitzianus*, Barr. (Grapt. de Bohême, extracted from the Silurian System of Central Bohemia.)

1850. Professor M'Coy described three new species of Graptolites — *G. lobiferus*, *G. millipeda*, and *Diplograpsus rectangularis*—and he proposed the generic name of *Diplograpsus* for forms with cellules on both sides, Barrande's name of *Diprion* having been previously applied to an insect. (Ann. and Mag. Nat. Hist., vi. 2d series, pp. 270-272.)

1850. Professor Harkness described and figured twelve species of Graptolites from the anthracitic shales (Upper Llandeilo) of Dumfriesshire. The species named were—*Rastrites peregrinus*, Barr., *Rastrites triangulatus*, Harkn., *Graptolites Sedgwickii*, Portl., *G. Becki*, Barr., *G. Nicoli*, Harkn., *G. Nilssoni*, Barr., *G. incisus*, Harkn., *Diplograpsus pennatus*, Harkn., *D. nodosus*, Harkn., *D. rectangularis*, M'Coy, *D. folium*, His., and *D. foliaceus*, Murch. (Quart. Journ. Geol. Soc., vii. pp. 59-65, pl. I.)

1851. Professor M'Coy published descriptions of sixteen species of Graptolites from the Silurian Rocks of Scotland,

Wales, and the North of England. The described forms were—*Graptolites convolutus*, His., *G. latus*, M'Coy, *G. lobiferus*, M'Coy, *G. Ludensis*, Murch., *G. millipeda*, M'Coy, *G. Murchisoni*, Beck., *G. sagittarius*, His., *G. Sedgwickii*, Portl., *G. tenuis*, Portl., *Diplograpsus foliaceus*, Murch., *D. folium*, His., *D. mucronatus*, Hall, *D. pristis*, His., *D. ramosus*, Hall, *D. rectangularis*, M'Coy, and *D. sextans*, Hall. At the same time M'Coy not only placed the forms with a double series of cellules under *Diplograpsus*, but also proposed the genus *Didymograpsus* for species consisting of two branches springing from the base. (British Palæozoic Fossils, pp. 3-9, pl. I. B.)

1851. Mr Salter described *Graptolites tenuis*, Portl., and *Diplograpsus bullatus*, Salt., from the Lower Silurian Rocks (Caradoc) of Scotland. (Murchison, Silurian Rocks of Scotland, Quart. Journ. Geol. Soc., vii. pp. 173, 174, pl. X. figs. 1, 2.)

1851. Dr H. A. Prout described a Graptolite, *G. Hallianus* (= *Dendrograpsus*), from the Potsdam Sandstone of the St Croix River. (Am. Journ. of Science (2), ix. p. 187.)

1851. Edward Suess published descriptions of Bohemian Graptolites, reproducing nearly all those described by Barrande, recognising several other known species, and describing nine new species. He also proposed the name of *Petalolithus* as a substitute for *Diprion* of Barrande. (Naturwissenschaftliche Abhandlungen, iv. pp. 88-134, pls. VII., VIII., IX.)

1851. Böeck; 'Bemærkinger Angaaender Graptolithen Christiania.'

1851. Scharenberg; 'Ueber Graptolithen.'

1852. Professor Geinitz contributed an important work on the Graptolites of the Silurian Rocks of Saxony. He placed the Graptolites amongst the Zoophytes, abandoning his former view that they were referable to the Cephalopoda. He proposed the genera *Monograpsus*, *Cladograpsus*, and *Nereograpsus*; and he enumerated altogether fifty species, of which several are new. (Die Versteinerungen der Grauwackenformation, Heft. I. Die Graptolithen.)

1852. Mr Salter described and figured from the Lower

Silurian Rocks of Scotland *Diplograpsus teretiusculus*, His., *G. sagittarius*, Linn., *G. Flemingii*, Salt., and *G. laxus*, Nicol (= *D. teretiusculus*, His.) (Quart. Journ. Geol. Soc., viii. pp. 388-391, pl. XXI. figs. 3-9.)

1852. Professor James Hall reproduced the *Graptolithus Clintonensis*, and described *G. venosus* (= *Retiolites*). He also described the genus *Dictyonema*, and the doubtful genus *Inocaulis*. (Pal. N. York, ii. pp. 39, 40, pl. XVIII.; and pp. 174-176, pls. XL. F and XL. G.)

1853. Mr Salter described a new species of Graptolite "from the Lauzon Precipice, Hudson River Group," under the name of *Didymograpsus caduceus*. (Quart. Journ. Geol. Soc., ix. p. 87.)

1855. Dr Emmons described several new species of Graptolites, and proposed the generic names *Nemagrapsus*, *Glossograpsus*, and *Staurograpsus*. (American Geology, i.)

1855. Professor Harkness communicated a paper on the Lower Silurian Rocks of the south of Scotland, in which he described a new Graptolite under the name of *Rastrites Barrandi* (= *Cænograpsus gracilis*, Hall). (Quart. Journ. Geol. Soc., xi. p. 475.)

1857. Professor Meneghini, from collections made by General De la Marmora, described ten species of Graptolites from the Silurian Rocks of the Island of Sardinia, of which eight species were new. (Palæontologie de l'Ile de Sardaigne.)

1857. Professor James Hall communicated to Sir William E. Logan descriptions of twenty-one new species of Graptolites from the Lower Silurian Rocks of Point Lévis (Lauzon Seigniorie) near Quebec, and proposed several new genera. (Report of Progress, Geol. Survey of Canada, 1857.—See also the Canadian Naturalist and Geologist, iii.)

1857. Mr Salter proposed the genus *Graptopora* for forms which had previously been referred by Hall to the genus *Dictyonema*. (American Association of Science, 1857.)

1859. Professor James Hall published 'Notes upon the Genus *Graptolithus*,' with an enumeration of the Canadian species. There was also a notice of Graptolite-stipes with

reproductive cells, together with descriptions of two new species. (Twelfth Report on the State Cabinet, Albany, pp. 45, 58, 1859.)

1859. The preceding Notes were reproduced with descriptions of five additional species of *Graptolithus*, one *Retiograptus*, the genus *Thamnograptus*, and one species of *Rastrites*. (Pal. New York, iii. pp. 495-522.)

1859. Mr W. Carruthers enumerated twenty-four species of Graptolites as occurring in the Anthracitic Shales (Upper Llandeilo) of Dumfriesshire, and added three additional forms to those already described—viz., *Cladograpsus linearis*, *Diplograpsus tricornis*, and *Didymograpsus Moffatensis*. (Ann. and Mag. Nat. Hist., 3d series, iii. No. 13.)

1860. Professor James Hall, in continuation of the paper from the 'Twelfth Report on the State Cabinet' (from Pal. New York, iii. Supp.), described additional species of *Graptolithus*, *Retiograptus*, *Thamnograptus*, and *Rastrites*, as above. (Thirteenth Report of the State Cabinet, p. 55-64. 1860.)

1861. Mr Salter, in 'New Fossils from the Skiddaw Slates,' noticed the occurrence in the Skiddaw Slates of several species of Graptolites, and proposed the genus *Dichograpsus* for some branching forms. (Geologist, i. p. 74.)

1861. Mr Billings communicated a paper "On the Occurrence of Graptolites in the Base of the Lower Silurian." (Canadian Naturalist and Geologist, vi. pp. 344-348.)

1863. Mr Salter (Note on Skiddaw-Slate Fossils) mentioned the occurrence of fourteen species of Graptolites in the Skiddaw Slates of the north of England. The genus *Phyllograpsus* was here for the first time recognised as occurring in Britain, and the genus *Tetragrapsus* was proposed for forms consisting of four monoprionidian stipes. (Quart. Journ. Geol. Soc., xix. pp. 135-140, with illustrations.)

1865. Professor James Hall published his extremely valuable and important monograph 'On the Graptolites of the Quebec Series of North America.' This classical work contains descriptions of no less than fifty-four species of Graptolites, of which all but two belong to the Quebec Group. They are described under the genera *Graptolithus*, *Diplograptus*,

Climacograptus, *Retiolites*, *Retiograptus*, *Phyllograptus*, *Dendrograptus*, *Callograptus*, *Dictyonema*, *Ptilograptus*, and *Thamnograptus*. Descriptions of nearly all the species here described were published, without illustrations, in the 'Report of Progress of the Geological Survey of Canada' for 1857. The value of the work is enhanced by an excellent Introduction on the general structure and affinities of the *Graptolitidæ*, and it is illustrated by twenty-three beautifully-executed plates, mostly engraved on steel, together with a large number of woodcuts. (Figures and Descriptions of Canadian Organic Remains.—Decade II. Graptolites of the Quebec Group.)

1866. Mr Salter described several species of Graptolites from the Lower Silurian Rocks of Wales. He refers the Graptolites to the *Polyzoa*, and described eight known forms, together with two new species—*Diplograpsus barbatulus*, and *Dendrograpsus furcatula*. (Mem. Geol. Survey, iii. pp. 328-333, pls. 11, A and B.)

1866. Dr H. A. Nicholson communicated a notice of some singular bodies which he had discovered in the Anthracitic Shales (Upper Llandeilo) of Dumfriesshire, and which he believed to be the ovarian vesicles of Graptolites. (Brit. Assoc. Rep. Nottingham, 1866; and Geol. Mag., iii. pp. 448, 449, pl. XVII.)

1867. Mr W. Carruthers communicated a paper on the systematic position of Graptolites. (Geol. Mag., iv. pp. 70-72.)

1867. Dr H. A. Nicholson described several species of Graptolites from the Lower Silurian Rocks of Dumfriesshire. Amongst these were two new forms—*Diplograpsus acuminatus* and *Didymograpsus anceps*—together with a fossil which was described under the name of *Corynoides calicularis*, as being most nearly related to the *Corynida*. (Geol. Mag., iv. pp. 107-113, pl. VII.)

1867. Mr W. Carruthers published a paper on the structure and affinities of the Graptolites, describing twelve genera, amongst which was the new genus *Cyrtograpsus*. The name *G. Hisingeri* was proposed for the familiar *G. sagittarius*, and three new species were described under the names of *G. Clin-gani*, *Didymograpsus elegans*, and *Rastrites capillaris*. (Intel-

lectual Observer, May and June 1867, pp. 283-292, pl. I., and pp. 365-374, pl. II.)

1867. Dr H. A. Nicholson described a branching Graptolite from the Upper Llandeilo Rocks of Dumfriesshire, which had been previously named by Mr Carruthers *Cladograpsus linearis*. The name *Cladograpsus* having been previously applied by Geinitz to the *Didymograpsi*, and no generic description being given in Mr Carruthers' paper, the name *Pleurograpsus* was proposed for this form. Further descriptions were given of the supposed reproductive bodies above alluded to, and a new *Diplograpsus* was described under the name of *D. Harknessii*. (Geol. Mag., June, iv. p. 256, pl. XI.; and Trans. Edin. Geol. Soc., i. p. 57.)

1867. Mr W. HELLIER Baily figured and gave numerous localities in Britain for several characteristic Llandeilo Graptolites. (Figures of Characteristic British Fossils. Part I. 23-26, pl. IX.)

1867. Dr H. A. Nicholson communicated two papers on the Nature and Zoological position of the Graptolitidæ, and on the Graptolites of the Skiddaw Series. (Brit. Assoc. Rep. Dundee, 1867.)

1867. Mr W. Carruthers published an account of British Graptolites in the Appendix to the fourth edition of 'Siluria.' A general account of the Graptolitidæ was given, with a summary and list of the British genera and species, several of the latter being named for the first time. (Siluria, fourth edition, Appendix, p. 538.)

1868. Dr H. A. Nicholson published the above-mentioned paper on the Nature and Zoological position of the Graptolitidæ. (Ann. and Mag. Nat. Hist., January 1868, pl. III.)

1868. Mr W. Carruthers published a paper under the name of a "Revision of British Graptolites, with Descriptions of New Species, and Notes on their Affinities." The paper was chiefly an expansion of the Appendix to the fourth edition of 'Siluria,' and the new species described were—*Rastrites maximus*, *R. capillaris*, *Graptolithus intermedius*, *G. Clingani*, *Cyrtograpsus Murchisoni*, *Didymograpsus elegans*, *Cladograpsus capillaris*, *Dendrograpsus lentus*, *Diplograpsus minutus*, *D.*

persculptus, *Climacograpsus minutus*, *Dicranograpsus Clingani*. (Geol. Mag., v. Nos. 44 and 45.)

1868. Professor Hall published an 'Introduction to the Study of the Graptolitidæ.' This was essentially a reprint of the 'Introduction to the Descriptions of the Graptolites of the Quebec Group;' but it contained some important alterations and additions. Amongst these may be mentioned the proposal of the genus *Loganograpsus* for forms with more than eight stipes and a central corneous disc. Mr Hall also proposed the name *Cænograpsus* for a new genus, to include the singular branching form originally described by him under the name of *Graptolithus gracilis*. (Twentieth Annual Report on the State Cabinet, Albany, 1868, pp. 167-240.)

1868. Dr H. A. Nicholson announced the occurrence of Hall's genus *Ptilograpsus* in the Ludlow Rocks of Ludlow, and described a new species under the name of *Ptilograpsus Anglicus*. (Ann. and Mag. Nat. Hist., April 1868, pp. 238-241.)

1868. Dr H. A. Nicholson proposed the genus *Helicograpsus* for Hall's *Graptolithus gracilis*, which had been placed by Carruthers in his genus *Cladograpsus*. (Ann. and Mag. Nat. Hist., July 1868, 4th series, ii. p. 23.)

1868. Dr H. A. Nicholson published an account of the Graptolites discovered by Professor Harkness and himself in the Skiddaw Slates of the north of England. In this paper twenty-five species were recognised as occurring in this formation, of which fifteen were now for the first time found in Britain. Of these, three species were described as new—viz., *Dichograpsus multiplex*, *D. reticulatus*, and *Pleurograpsus (?) vagans*. (Quart. Journ. Geol. Soc., xxiv. pp. 125-145, pls. V. and VI.)

1868. Dr H. A. Nicholson announced the discovery of a rich Graptolitic fauna in a small group of beds succeeding the Coniston Limestone in the north of England. From these beds, and from the overlying Coniston Flags, the author described twenty-four species of Graptolites. Of these *Diplograpsus putillus*, Hall, *D. angustifolius*, Hall, *Graptolites Boheemicus*, Barr., *G. colonus*, Barr., and *G. turriculatus*, Barr., were

for the first time described as occurring in Britain, and *Diplograpsus confertus*, *D. tamariscus*, *Graptolites discretus*, *G. fimbriatus*, and *Retiolites perlatus* were described as new species. (Quart. Journ. Geol. Soc., xxiv. pp. 521-545, pls. XIX. and XX.)

1868. Dr H. A. Nicholson published a paper on the Distribution in Time of the British species and genera of Graptolites. (Ann. and Mag. Nat. Hist., Nov. 1868, 4th series, ii. pp. 347-357.)

1869. Mr W. Hellier Baily published a paper on the localities in Ireland in which Graptolites are found, with lists of the species. (Quart. Journ. Geol. Soc., xxv. pp. 158-162.)

1869. Mr John Hopkinson published a paper on British Graptolites, in which he divided them into four sections—*Monoprionidæ*, *Diprionidæ*, *Monodiprionidæ*, and *Tetraprionidæ*. (Journ. Quekett Microscopical Club, i. No. 6.)

1869. Dr H. A. Nicholson described and figured fifteen new species of Graptolites from the Lower Silurian Rocks of Britain. Of these, seven were from the Skiddaw Slates, and comprised one new genus (*Trigonograpsus*), with one species (*T. lanceolatus*), two new species of *Dichograpsus* (*D. fragilis* and *D. annulatus*), two *Diplograpsi* (*D. Hopkinsoni* and *D. armatus*), and two *Didymograpsi* (*D. affinis* and *D. fasciculatus*). Three species were from the Mudstones of the Coniston Series—viz., *Diplograpsus Hughesi*, *D. sinuatus*, and *Graptolites argenteus*. Five species were from the Upper Llandeilo Rocks of Dumfriesshire—viz., *Diplograpsus bimucronatus*, *D. insectiformis*, *D. vesiculosus*, *Climacograpsus innotatus*, and *C. tuberculatus*. (Ann. and Mag. Nat. Hist., Oct. 1869, 4th series, iv. pp. 231-242, pl. XI.)

1870. Mr Charles Lapworth read a paper on the Lower Silurian Rocks of the south of Scotland before the Geological Society of Edinburgh. In this communication the author recognised the occurrence of a higher Graptolitic zone above the well-known Anthracitic Shales of Dumfriesshire. In this zone—which he paralleled with the Mudstones of the Coniston Series in the north of England—the author recognised a large number of Graptolites, amongst which *G. turri-*

culatus, Barr., *G. colonus*, Barr., *Retiolites Geinitzianus*, Barr., and *R. perlatus*, Nich., were new to Scotland. (Read before the Geol. Soc., Edinburgh, 3d March 1870.)

1870. Dr H. A. Nicholson described and figured fourteen species of *Didymograpsus*, known to him as occurring in Britain.

1870. Mr John Hopkinson published a paper on the Structure and Affinities of the Genus *Dicranograpsus*. In this he referred *Didymograpsus sextans*, Hall, to the genus *Dicranograpsus*, and described two new species under the names of *D. formosus* and *D. Nicholsoni*. (Geol. Mag., vii. No. 8, Aug. 1870.)

1870. Dr H. A. Nicholson published a paper on the genus *Climacograpsus*, and the British species of the same. (Ann. and Mag. Nat. Hist., Nov. 1870.)

1871. Mr John Hopkinson proposed the name of *Dicellograpsus* for certain forms previously referred to the genus *Didymograpsus*. (Geol. Mag., Jan. 1871.)

1871. Mr John Hopkinson described a specimen of *Diplograpsus pristis*, with reproductive capsules, from the Upper Llandeilo Rocks of Dumfriesshire. (Ann. and Mag. Nat. Hist., May 1871.)

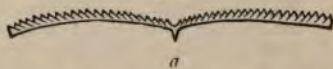
CHAPTER II.

FORM AND MODE OF PRESERVATION OF GRAPTOLITES.

THE exact nature and systematic position of the Graptolites is a question upon which many different opinions have been advanced, and I shall discuss it at full length when I have spoken of the morphology of these organisms, and of their reproduction and development. In the meanwhile, it is sufficient to say that the preponderance of authority is in favour of the view that the Graptolites find their nearest living allies in the Sertularian Zoophytes or "Sea-firs." I shall therefore assume the correctness of this view in what follows as to the general structure of the *Graptolitidæ*.

GENERAL FORM OF GRAPTOLITES.—Graptolites occur as linear, rarely leaf-like, simple, or branched bodies (fig. 3), which are undoubtedly the skeletons of composite organisms or colonies of semi-independent zooids, which may be well compared to the living Sea-firs (*Sertularida*) or the Sea-mosses and Sea-mats (*Polyzoa*), altogether irrespective of the particular view which may be held as to their true zoological affinities. The skeletons constitute all that is preserved to us of the Graptolites, and little doubt can be entertained as to their being composed of some flexible horny material, which we may safely conclude to be identical with the "chitine" which forms the outer investment of the colonies of the Ser-

Fig. 3.



a, Small specimen of *Didymograpsus patulus*, Hall, from the Skiddaw Slates of Outerside, near Keswick. Nat. size. (Original.)

tularians. The horny or chitinous skeleton of the Graptolites may also be safely called by the general term of the "polypary," applied to the similar structures in the Sea-firs.

In its general and its simplest expression, the polypary of a typical Graptolite (fig. 4) consists of a row of horny cups, united at their bases by a common tube into which they open, and which is formed by a chitinous investment continuous with the bases of the cups. Very generally, the entire organism thus constituted is supported by a fibrous cylindrical rod, which often projects in a naked form beyond one or both

Fig. 4.



A, *Graptolites colonus*, Barr. From the Coniston Grits of the north of England. Slightly enlarged. B, Fragment of the same enlarged, showing the cellules (*h*), the common canal (*c*), and the solid axis (*a*). C, *Diplograpsus tamariscus*, Nich., from the Coniston Mudstones of the north of England. Enlarged. D, *Diplograpsus palmeus*, Barr., from the Coniston Mudstones. Enlarged. E, *Diplograpsus folium*, His., from the Coniston Mudstones. Enlarged. (Original.)

ends of the general polypary. The little cups give a serrated or dentated appearance to the polypary, or, as it is often called, the "frond;" and there can be no doubt that in the living state each cup contained a single zoöid, or one of the separate factors, which together make up the composite organism. These little cups have been generally termed the "cellules" or "calyces." The tube into which all the cellules open is called the "common canal," and no doubt, in this case also, can be entertained but that this tube, in the living

state, was filled with a common flesh, by which all the zooids of the colony were brought into organic connection, and from which they were budded forth. The common canal, therefore, corresponds with what is known as the "coenosarc" of the Hydroid colony. Lastly, the fibrous rod by which the frond is supported is known by the name of the "solid axis."

The above gives the general structure of the polypary or "frond" of one of the simplest forms of Graptolites (such as *G. colonus*, Barr., fig. 4, A); and in the great majority of cases the more complex forms are seen to be produced by the combination in different ways of a greater or less number of these simpler factors. The term "frond," then, may be applied to the entire polypary of any Graptolite, whether this be simple and composed of one such factor, or compound and composed of two or more of such factors united in different ways. It only remains to add that the term "stipe"* may be advantageously applied to the separate simple elements which make up the complex species, each stipe having the general structure just described.

Finally, all those forms in which the cellules are arranged in single rows upon one side of the stipe or frond only, are

* The terms "frond" and "stipe," nearly as above defined, were originally proposed by Professor James Hall, but their use has been objected to upon the ground that they are botanical terms, and therefore liable to mislead. Though personally believing that the Graptolites are referable to the *Hydrozoa*, I shall nevertheless in the meanwhile adhere to the above phraseology, upon the ground that competent observers would still refer the Graptolites to the *Polyzoa*. The more precise Hydrozoal terminology proposed by Mr Carruthers would therefore not be universally accepted. The same objection cannot be advanced against the use of the term "polypary," since this has been commonly applied indifferently to the skeletons of the *Hydrozoa* and *Polyzoa* alike. The Graptolites, also, are in many respects so unlike any living organisms, that the use of a special terminology is far from being undesirable. And it can hardly be that the mere fact of the above terms having been employed in botany should materially interfere with the facility with which the subject of the *Graptolitidæ* may be comprehended. Upon similar grounds, I am not disposed to abandon the use of the term "cellules," as applied to the little cups in which the nutritive zooids of the Graptolite colony were contained. Undoubtedly, if the Graptolites were universally admitted to be Hydroid Zoophytes, then the use of the term "hydrothecæ" would be greatly to be preferred. This is not so, however; and it seems safer in the meanwhile to adhere to the old terminology, as implying no theory as to the nature of the Graptolites.

termed "monoprionidian" (fig. 4, A, B), irrespective of their being simple or compound. On the other hand, those forms which have the cellules arranged in two rows, one on each side of the frond, are said to be "diprionidian" (fig. 4, C, D, E).

MODE OF PRESERVATION OF GRAPTOLITES.—The manner in which Graptolites have been preserved as fossils varies much in different cases, and it is absolutely impossible to overrate the importance of a clear comprehension of this subject, since the phenomena presented depend almost entirely upon this circumstance; whilst it is one to which far too little attention has been paid. The modes in which the polyparies of the Graptolites have been preserved may be considered under the following four heads:—

1. The corneous polypary, which is all that constitutes the Graptolite as a fossil, has been simply *flattened out* and crushed. In this case, the one side of the stone exhibits the frond in this crushed condition, whilst the other side merely exhibits a cast of the same. The polypary may be simply carbonised, or may be converted into iron pyrites, the former occurring more commonly in rocks of a light colour, whilst the latter takes place generally in rocks of a dark-grey or black colour. This state of preservation is the common one in the Graptolites of the Quebec Group of Canada, the mudstones, sandstones, and shales of the Ludlow and Wenlock Rocks of Britain, and the Coniston Grits of the north of England. It occurs also in some of the specimens from the mudstones of the Coniston Series, the Upper Llandeilo Rocks of Dumfriesshire, and the Hudson River Shales of N. America, though it is rare in the two last-mentioned deposits.

2. The polypary is converted into pyrites, but, from some peculiarity in the process of fossilisation or the nature of the enveloping rock, it is no longer separable from the matrix, so as to present us with a cast on one side of the stone and the actual body on the other. On the contrary, we now find that, in separating the rock into its component laminae, the fossil becomes divided into two exactly similar halves, one on one surface and one on the other. Consequently, in this case,

what we really obtain is a *section* of the Graptolite, generally along what approaches more or less nearly to its median plane. It is as if the entire cavity of the Graptolite had been filled with glistening pyritous matter, differing in no way as regards texture from the enveloping matrix, and conjoined with it in a wholly inseparable manner, at the same time that the margins of the fossil remain distinct. When the rock, therefore, is divided, the two halves of the stone present exactly the same appearances, since they really show *sections* of the organism. That this is truly the case can be conclusively shown by artificially removing thin layers of the rock embracing a Graptolite so preserved. When this is done, it is seen that the Graptolite extends through the thickness of the stone, and that the removal of a thin layer merely shows us on the layer below another almost precisely similar representation of the same fossil. It is most important to bear this constantly in mind, as much of the difficulty which has been experienced in the interpretation of the Graptolites has arisen from this fact, and many errors have been caused by its non-recognition. This is especially the case as regards the determination of species, since the same Graptolite exhibits often an entirely different form according as it is preserved in the above manner or in relief. This is shown particularly well in specimens in which one part of the frond is preserved as above, while the remainder is in relief; in which case the two portions may differ from one another so much that, if found separate, they would certainly be described as belonging to distinct species (fig. 5).*

In this state of preservation occur most of the Welsh and Irish Graptolites, some of those from the Skiddaw Slates (especially in the upper beds), many of those from the mudstones of the Coniston

Fig. 5.



Specimen of *Graptolites Sedgwickii*, Portl., var. *spinigerus*, Nich., in which the lower portion of the frond is preserved in relief, and the upper portion in section. Nat. size. (Original.)

Series, almost all those from the Upper Llandeilo Shales of Dumfriesshire, and the majority of those in the Silurian Rocks of Bohemia, and the Hudson River and Utica Shales of North America.

3. The entire substance of the polypary has been removed, and nothing is left but a hollow cast of the frond. In this state occur a few specimens from the mudstones of the Coniston Series, and some of the best specimens from the Skiddaw Slates.

4. The space included in the interior of the polypary has been filled wholly with iron pyrites, or with the sediment of the surrounding matrix. We thus get a solid cast of the frond, from which the polypary itself may have been removed, though it is more commonly preserved and converted into pyrites. This is by far the most beautiful and perfect state of preservation in which Graptolites ever occur; and when thus preserved, their study is comparatively easy. In this state are found most of the Graptolites of the mudstones of the Coniston Series, many of those from the Coniston Flags, some of those from the Coniston Grits, a few of those from the upper beds of the Skiddaw Slates, and very few, comparatively speaking, of those from the Upper Llandeilo Rocks of Scotland.

SEDIMENTS IN WHICH GRAPTOLITES OCCUR.—As regards the mode of occurrence of Graptolites, it only remains to add that they are very generally found in strata which are of the nature of shale, mudstone, or flagstone, and which have a prevailing dark-grey or black colour. This rule, however, is by no means universal. Graptolites sometimes occur in sandy or gritty beds, and sometimes in limestone; and they occur not uncommonly in such rocks as the light-yellowish shales of the Coniston Grits, or the greenish or yellowish mudstones of some portions of the Ludlow Rocks. In the Upper Llandeilo Shales of Dumfriesshire and Ayrshire, the mudstones of the Coniston Series, and other formations, the Graptolites mostly occur in strata which are more or less anthracitic in appearance, and which, in some cases at any rate, have been shown to contain carbon to the amount of as much as five per

cent (Harkness). The exact origin of the carbon in these cases cannot be considered as absolutely free from doubt; but it is in all probability of animal origin, and can hardly be ascribed to anything else except the Graptolites themselves, since no plants of any kind, and hardly any other animal remains, have ever been detected in these rocks. At the same time, some of the most highly anthracitic beds exhibit no traces of Graptolites.

CHAPTER III.

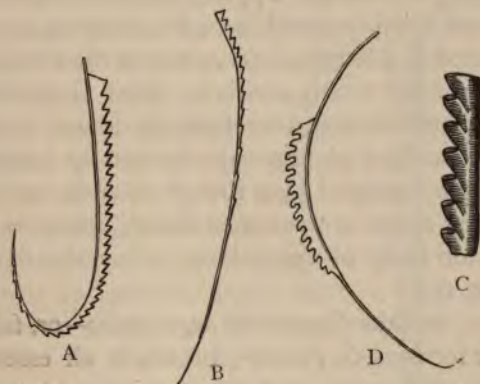
GENERAL MORPHOLOGY OF GRAPTOLITES.

IN considering the general morphology of the typical Graptolites, it will be best to take two or three of the simplest forms, such as *Graptolites sagittarius*, His., *G. colonus*, Barr., and *Climacograpsus teretiusculus*, His., from which the general structure will readily be comprehended.

If we take a perfect young individual of *Graptolites sagittarius* (fig. 6, A), we are presented with a curved linear body, the entire length of which is perhaps not as much as one inch, though it may considerably exceed this. The slenderest portion of the frond is curved up, and it constitutes the organic base of the organism, or what would properly be termed the "proximal" end of the polypary. It commences in delicate triangular process (fig. 6, A), or in a long fibre (fig. 6, B), which I shall afterwards speak of at length under the name of the "radicle" or "initial point." The concave side of the frond is seen to be bordered by a plain margin, along which runs a cylindrical fibrous rod, the "solid axis," which is seen to be continued as a naked process beyond the "distal" end of the polypary, or the end opposite to the radicle (fig. 6, A). The convex side of the frond is indented with little serratures, so that this margin assumes a toothed appearance like that of a saw, whilst from the point of each serrature a straight or nearly straight line is directed inwards towards the solid axis (fig. 6, C). The outer margin of the serrature is also bounded by a line which is directed inwards towards the axis at a given angle. The inner margin of the serrature is formed by a line

which is the outer boundary of the serrature above. The space marked off by these lines is (in the specimen I am describing) the *section* of one of the tubular compartments or cups, in each of which one of the zoöids of the entire colony was formerly contained, and which I have already spoken of as the "cellules." The tooth-like extremity of the cellule is often termed the "denticle," and it marks the position of the

Fig. 6.



A, Young individual of *Graptolites sagittarius*, His., showing the slender curved base of the frond, and the extension of the axis beyond its opposite end; B, Base of another individual of the same, in which there is an extremely long "radicle;" C, Fragment of *G. sagittarius*, much enlarged to show the cellules—from a specimen in relief; D, Specimen of *Graptolites Clingani*, Carr., showing the distal and proximal extensions of the axis. A and B are from the Upper Llandeilo Shales of Dumfriesshire, and are slightly enlarged. C and D are from the Coniston Mudstones, both considerably enlarged. (Original.)

original opening of the cellule, from which the contained zoöid had the power of protruding its tentaculate distal extremity or head. The "outer" margin, therefore, of each denticle, is to be looked upon as more or less accurately indicating the position of the "cell-mouth" or "cell-aperture." The distinct impressed lines which mark off each cellule above and below, are known as the "cell-partitions." These partitions, as I have before said, are directed inwards towards the axis at a given angle, but they do not quite reach the axis. Between the bases of the cellules and the solid axis is a con-

tinuous space which extends from the radicle to the distal extension of the axis (fig. 4, B, c), and which has been already spoken of as the "common canal." It constitutes a continuous tube, which was originally filled with the common flesh or organic substance from which the separate zooids were budded off; and it corresponds, therefore, with the "cœnosarc" of the living *Hydrozoa*.

The specimen of *G. sagittarius* (fig. 6, A) which I have just been describing is from the Upper Llandeilo Shales of Dumfriesshire; and it is preserved in such a manner, that what is really exhibited is a longitudinal *section* of the polypary along a plane more or less nearly median. Most Graptolites occur in this state, and exhibit, therefore, the above appearances. They show, namely, a plain margin limited by a solid fibre, a serrated margin occupied by a row of cellules, and an intermediate vacant space or "common canal," formerly occupied by the common body of the colony. (See the figure of *G. colonus*, fig. 4, A.)

If, however, we take *Graptolites sagittarius*—or, failing this, such another form as *G. priodon*, Bronn, in all essential anatomical points the same—and examine it in a state of *relief*, we find the following condition of parts. We find that we have now a nearly cylindrical body (fig. 7, A), which commences in an attenuated base, and gradually widens out, so that it is, strictly speaking, a greatly-elongated cone. One side of the cylinder is gently rounded, and is marked by a continuous groove, in which is still lodged in part the "solid axis," in the form of a fibrous rod running the entire length of the polypary (fig. 7, B). When we look at the frond upon this aspect—namely, upon the side on which the solid axis is situated—there is seen on each side of the dorsal groove containing the axis, and running parallel with the same, a narrow space which is perfectly plain and free from grooves or lines of any kind. These lateral spaces together mark the position of the "common canal." At the outer margins of the spaces thus indicated commence the "cell-partitions" in the form of a series of grooves, which run round the cylinder to meet on the side diametrically opposed to the solid axis.

The cell-partitions springing from the opposite sides of the axis ultimately meet on the abaxial aspect of the frond in a small opening or "cell-aperture." When, therefore, we look upon the frond upon the side opposed to the axis, we see a vertical series of small openings which represent the mouths of the cellules (fig. 7, C). In the particular species now under consideration, the cellules have a peculiar curved shape, and taper much in proceeding from their bases towards their mouths (fig. 7, A), whilst the outer portion of each cellule is free, and is not in contact with the cellules immediately above and below. The result of this is, that on transverse section of the frond (fig. 7, D) we have not got a perfect cylinder, but a triangle with rounded angles, the apex of which is constituted by the cell-mouth, whilst the solid axis runs in the centre of the base.

The structure of such a simple Graptolite as *G. sagittarius*, His., or *G. priodon*, Bronn, as just described, is essentially the structure of all the forms which are now placed in the genus *Graptolites* or *Graptolithus*, as defined by British palæontologists; and almost all the other forms can be shown to be formed by the aggregation and combination of two or more of such simple forms in different modes. Such a simple form, then, constitutes the simplest expression of the structure of the Graptolites; and the more complex forms are, in the majority of cases, simply produced by the building up of factors similar to this and to one another. It is to be remembered, however, that there are some forms not

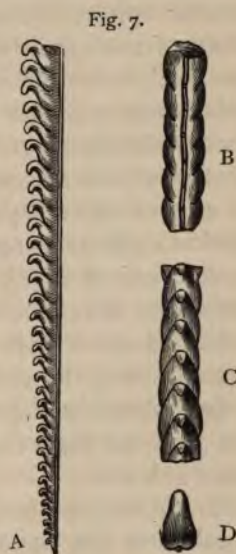


Fig. 7.
A, *Graptolites priodon*, Bronn, preserved in relief. Lateral view slightly enlarged. B, Dorsal view of a fragment of the same species: considerably enlarged. C, Front view of a fragment of the same, showing the mouths of the cellules: much enlarged. D, Transverse section of the same. All from the base of the Coniston Flags. (Original.)

at present separable from the typical Graptolites, which depart from the above characters in points which are probably of at least ordinal value. The peculiarities of these forms will be noticed in treating of the various genera of the *Graptolitidae*.

Before passing on to consider one of the less complicated of the compound Graptolites—as throwing further light upon the general morphology of the family—I should mention a peculiar appearance which is often presented by the simple forms of the genus *Graptolites*. In most cases, as already remarked, the state of preservation is such that we are presented with a *section* of the frond, the two surfaces of the stone exhibiting precisely similar appearances. In these cases we almost always get *lateral* views of the frond, showing the axis on one margin, and the cellules on the opposite serrated margin (as in fig. 2, *e*). When, however, the polypary is preserved in relief, or in such a manner that the one surface of the stone shows the compressed frond, and the other surface shows a cast of the same, we may get several dissimilar views. Remembering, namely, that the simple frond is approximately a cylinder (as shown in fig. 7, D), we recognise that we may be presented with at least three distinct views of it:—

Firstly, we are presented with a profile or side view of one or other of the lateral surfaces of the frond, as in fig. 7, A. This is what most commonly occurs.

Secondly, we have a view of the frond from its hinder or *axial* aspect. In this case (as in fig. 7, B) we find the margins of the frond nearly or quite plain, the solid axis running up its centre, bordered on each side by a narrow vacant space representing the common canal, and the bases of the cell-partitions indicated as impressed lines at the margins of the whole.

Thirdly, we may have a view of the frond from its front, so to speak—that is to say, we get a view of that surface of the cylinder which is diametrically opposed to the solid axis, and along which the mouths of the cellules are placed. In this case (as in fig. 7, C, and fig. 2, *a*) we have a linear body,

with plain non-serrated margins, traversed by a number of transverse, lunate, elliptical, or nearly straight fissures, which are the cell-apertures. The solid axis is, of course, concealed by the thickness of the polypary, unless, as sometimes happens, the frond has been greatly compressed. Such views of any Graptolite are said to be "scalariform," upon the questionable belief that the original *Graptolithus scalaris* of Linnaeus was founded upon an impression of this nature. Be this as it may, it is unquestionable that such scalariform impressions of "monoprionidian" Graptolites (*i. e.*, Graptolites with a single row of cellules) do actually occur, and are, indeed, not uncommon. That many of the figures given by Barrande and Geinitz as the scalariform views of monoprionidian Graptolites are truly figures of genuine "diprionidian" forms (*i. e.*, forms with two rows of cellules) seems certain. I have, however, before given reasons (p. 3) for the assertion that "scalariform" impressions of monoprionidian species are of no rare occurrence in any deposits which yield more than mere *sections* of the Graptolites contained in them.

The above, then, are the three chief views in which a simple monoprionidian Graptolite may be exhibited; but it is quite clear that there must be many cases in which we are presented with views intermediate between some two of these. Thus, we may have a view which is partially, but not perfectly lateral, and this may show more of the posterior or axial surface, or more of the anterior or celluliferous surface, as the case may be. We may, therefore, and frequently do, obtain views which are "semi-scalariform," or which exhibit the lateral serratures less prominent than they would be in a perfectly lateral view. Hence the determination of species from the cellules is often rendered a matter of considerable difficulty, and, in the case of fragments, always more or less unreliable.

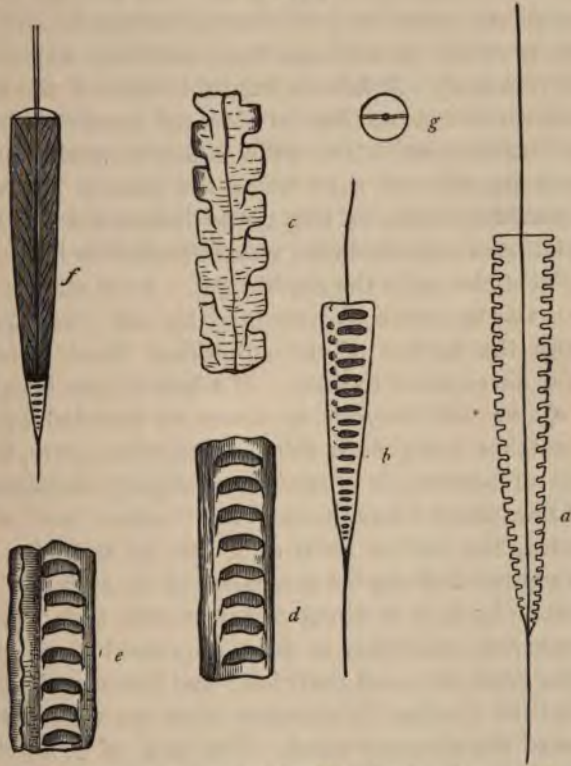
I may now shortly describe the structure of such a form as *Climacograpsus teretiusculus*, His., as exhibiting another type of structure amongst the Graptolites. In this form (fig. 8) we have a double-celled or "diprionidian" species, composed of two such simple cylinders as I have described in *G. sagittarius*

or *G. priodon*, placed back to back, so that the axial surfaces of the two are firmly united to one another. In this case, however, we must imagine that the two cylindrical simple stipes are so compressed that the back or axial surface of each becomes flattened into a plane (fig. 8, *g*). In place, therefore, of two cylinders united along a single line, we get two *half-cylinders* united along a plane; and the whole frond forms a single cylinder. As, however, each of the component half-cylinders tapers rapidly towards the base, the whole cylinder assumes the form of a greatly-elongated cone (fig. 8, *b* and *f*). The frond, then, in *Climacograpsus*, consists of two simple unicellular stipes placed back to back, in such a manner that their internal or dorsal walls coalesce to form an apparently single, but really double, partition or septum, by which the polypary is divided into two separate and independent halves. Each of these moieties has its own common canal and its own row of cellules springing therefrom; and the cell-mouths open in a vertical series on each of the lateral margins of the frond (or the margins furthest removed from the median septum, fig. 8, *a*). The solid axis is present in the form of a delicate fibrous rod, which is placed in the centre of the median septum, between its component laminæ (fig. 8, *g*). Lastly, the solid axis is always prolonged as a naked process beyond the distal end of the polypary; and there is almost always a similar extension beyond the basal or proximal extremity (fig. 8, *b*).

In order to comprehend fully the structure of *Climacograpsus*, it may be advantageously compared to an ordinary lead-pencil. Such a pencil, when taken to pieces, is found to consist of two longitudinal semicircular halves, applied to one another by their flat surfaces, and having the lead running through the centre as a median rod. This is almost exactly the structure of *C. teretiusculus*. Each half of the pencil corresponds to one of the stipes composing the frond, the lead represents the solid axis, and the glue cementing together the two halves of the pencil may be taken to represent the vertical septum formed by the coalescence of the two internal walls of the stipes. To make the analogy complete,

we have only to suppose that the pencil tapers gradually towards one of its ends, whilst the lead should be prolonged beyond one or both extremities, and a row of transverse openings should exist on the convex side of each of the lateral halves.

Fig. 8.



- a*, Specimen of *Climacograpsus teretiusculus*, His., showing the notch-like cell-apertures and the distal and proximal extensions of the axis; twice the natural size: from the Upper Llandeilo Shales of Dobb's Linn, near Moffat. *b*, Specimen of the same in a scalariform view, showing the mouths of the cellules; twice the natural size: Upper Llandeilo, Garple Linn, near Beattock. *c*, Specimen of the same in relief, showing the cell-partitions and suture; much enlarged: Coniston Mudstones, Skelgill Beck, near Ambleside. *d*, Fragment of a scalariform specimen of the same, much enlarged: Dobb's Linn, near Moffat. *e*, Another fragment, greatly enlarged: Skiddaw Slates. *f*, A specimen in relief, but split in half till close upon the base, showing the median septum and the solid axis running along its centre; twice the natural size: Mudstones of the Coniston series. *g*, Transverse section of a specimen of *C. teretiusculus*, preserved in the round, showing the median septum and the solid axis. (Original.)

Owing to a peculiarity in the form of the cellules of *Climacograpsus*, which it is not necessary to notice here at any length, the margins of the frond do not exhibit the lateral serratures which are so conspicuous in such a form as *G. sagittarius* (fig. 6), or in all the members of the nearly-allied genus *Diplograpsus* (fig. 4, C). On the contrary, the cell-mouths, in place of projecting prominently, are in the form of rounded or sub-quadrate notches, when viewed laterally (fig. 8, *a*). It follows from this that all the views of the frond which can possibly be obtained appear to be more or less "scalariform." The cellules are so welded together that their mouths are sunk below the general surface, and are separated by more or less tumid interspaces; hence the impossibility of ever obtaining views which show lateral serrations or denticles, as in the *Diplograpsi*. As in all other cases, however, the appearances presented by any given specimen vary with the surface of the cylindrical frond which may happen to be exposed to view. If a lateral view is exhibited (fig. 8, *a*), we find the cell apertures as rounded or nearly square notches along each side. Along the centre, between the rows of notches, is a straight or slightly-undulating impressed line, which I have termed the "suture," and which is constituted, not by the solid axis, but by the edge of the median septum dividing the two halves of the cylinder. From each notch (fig. 8, *c*) is directed downwards and inwards, in well-preserved examples, a short impressed line, which is really the edge of a cell-partition; and between the bases of these and the "suture" is a narrow plain space indicating the position of the common canal. This view of *C. teretiusculus* was originally described by M'Coy as a distinct species, under the name of *Diplograpsus rectangularis*. If, on the other hand, either of the two surfaces on which the cellules open be exposed, we get the appearances shown in fig. 8, *d*, *e*. We get, namely, an impression bounded by perfectly plain lateral margins, and exhibiting a number of transverse, lunate, or elliptical slits or apertures. This is a true "scalariform" view, in the sense in which we use the term as applied to a monoprionidian species. In well-preserved specimens ex-

hibiting this view, two faint lines proceed outwards and downwards, one from each angle of the transverse aperture, marking the position of the cell-partitions. The "suture" may be exhibited if the view is slightly oblique (as in fig. 8, *e*); but very often the suture is wholly invisible (fig. 8, *d*). The solid axis is, of course, not visible directly, except beyond the two extremities of the frond proper; but it is not uncommonly traceable in much-compressed specimens; and in these, too, it is far from infrequent for the apertures of the row of cellules on the opposite side of the frond to be seen indistinctly through the test. Between these extreme terms (as shown in fig. 8, *a* and *b*) intermediate forms exist in great variety, varying in every possible way with the exact portion of the surface of the frond which may be exposed to view.

CHAPTER IV.

SPECIAL MORPHOLOGY OF GRAPTOLITES.

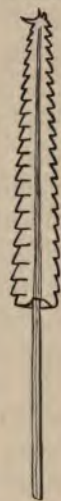
I. THE SOLID AXIS.—Having now treated in a general way of the morphology of some of the simpler forms of Graptolites, it becomes necessary to study their structure in greater detail, reserving, however, some minutiae till I come to speak of the generic types of the *Graptolitidæ*. The first structure which I may notice is that which has already been spoken of as the "solid axis." This is present in all the more typical members of the family, and has the form of a cylindrical fibrous rod, the diameter of which is stated by M. Barrande to be no more than $\frac{1}{4}$ millimetre (Grapt. de Bohême, p. 4). The general form of the axis is shown in any of the specimens in fig. 7, where it is seen to be a fibre running along the margin of the frond opposite to that on which the cellules are situated. The exact structure of the axis is a matter of doubt, but there is good reason to think that it is hollow, in place of being truly solid, as its name would imply. Thus Hall has stated (Grapt. Quebec Group, p. 22) that it occasionally, in much-compressed specimens, exhibits a longitudinal groove or line of division, its aspect being "precisely that which a hollow cylindrical body would have if extremely compressed." I have observed the same phenomenon in examples of *Diplograpsus pristis*, His. (fig. 9), and I am inclined to think that this is truly the correct explanation. It is to be remembered, however, that the solid axis of the double-celled Graptolites, such as the above, is in all probability a double structure, being primitively composed of the

two axes belonging to the separate stipes which make up the frond.

The function of the solid axis can hardly be other than that of giving support to the flexible polypary; but it may have subserved other purposes as well. As regards its homologies, nothing similar can be pointed to in any living *Hydrozoön*. Professor Allman, however, has described recently (Quart. Journ. Microscopical Science, Jan. 1869) a most remarkable *Polyzoön* in which such a structure is present. The polypidom of this curious form, which has been named *Rhabdopleura*, is a branched adherent tube, along the adherent side of which runs a rigid chitinous rod. This rod may well be compared with the solid axis of the Graptolites, especially of forms like *Dichograpsus*, in which the polypary is branched. It is also worthy of notice that the chitinous rod of *Rhabdopleura* is described as containing an axile channel, which in the younger parts of the coenecium is filled with a granular pulp, but which appears to be nearly or quite obliterated in the older parts. This fact, therefore,

would lend great support to the view that the solid axis of the Graptolites is truly tubular, and this view may be still further strengthened upon theoretical considerations. It is certain, namely, as we shall see immediately, that the solid axis is often prolonged far beyond one or both ends of the actual polypary, as a naked rod-like process; and it is very difficult to see how its growth was conditioned if we suppose it to be truly solid. If, on the contrary, we assume that the solid axis was perforated by a delicate canal, containing, as in *Rhabdopleura*, an organic pulp, it is then easy to see how the axis might grow independently of the rest of the colony, and might thus extend itself beyond the limits of the common canal or coenosarc. It is to be

Fig. 9.



Specimen of *Diplograpsus pristis*, His., slightly enlarged, showing the axis at the distal extremity with a longitudinal groove, as if it had been originally hollow. (Original.)

noticed, also, that the solid axis of the simple monopronidian Graptolites, and of the majority at any rate of the diprionidian forms, can be shown to be truly *outside* the polypary. This can be seen extremely well in specimens of *G. priodon*, Bronn (fig. 7, B and D), preserved in relief, in which the solid axis is found to occupy a longitudinal groove along the back of the stipe, *outside* the general periderm. Similarly, in *Climacograpsus teretiusculus*, His. (fig. 8, g), it can be shown that the solid axis is placed between the two laminae which form the vertical septum whereby the frond is divided into two compartments. From this, therefore, it is evident that the axis is in no sort of connection with the common canal, and could not derive nourishment from the coenosarc contained therein.

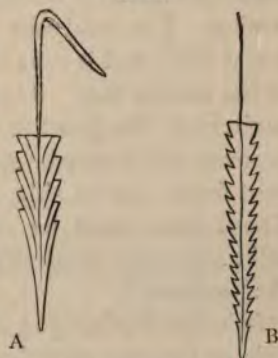
In the members of the genus *Graptolites* a solid axis is universally present, and in young specimens is prolonged as a naked process beyond one or both ends of the polypary, the distal prolongation being the most constant and the longest (see fig. 6). It may be questioned, however, if the distal prolongation of the axis occurs in mature examples of any species of the genus *Graptolites*, with the single exception of *G. colonus*, Barr. (fig. 4, A), in which it is undoubtedly, and probably constantly, present. The distal terminations of these forms, however, in their fully-grown condition, may be said to be unknown, so that this point may be regarded as doubtful.

The solid axis appears to exist with the same characters in all the monopronidian Graptolites referable to the compound genera, *Didymograpsus*, *Dichograpsus*, *Tetragrapsus*, *Pleurograpsus*, and *Helicograpsus* (or *Cænograpsus*). It seems certain, however, that in none of these forms is there ever any distal extension of the axis beyond the general substance of the polypary.

In all the double-celled or "diprionidian" Graptolites, constituting the genera *Diplograpsus*, *Climacograpsus*, and *Dicranograpsus*, a solid axis is present, and it seems to have the same form as in the simpler types. In almost all the *Diplograpsi* and *Climacograpsi* the solid axis appears to be invariably prolonged beyond the distal end of the polypary to a

greater or less extent (fig. 8, *a*, and fig. 9), as a naked process which is altogether devoid of cellules. In most of the species, such as *Diplograpsus pristis*, His., and *Climacograpsus teretiusculus*, His., this prolongation of the axis is universally present in every single specimen in which the distal end of the frond is preserved. There is therefore no adequate ground for the belief that this condition of parts is due to any artificial removal of the cellules prior to fossilisation. On the contrary, even the very youngest forms of these double-celled forms which have come under my notice show exactly the same distal prolongation of the axis; and it seems, therefore, unquestionable that this is the normal state of things. Still there are forms, such as those usually described as *D. folium*, His. (fig. 4, E), in which this distal prolongation of the axis is, to say the least of it, not always apparent, though it certainly is usually present. In most, again, of the *Diplograpsi* and *Climacograpsi*, the solid axis is also prolonged beyond the basal or proximal end of the polypary. In most cases this proximal extension of the axis is not more developed than as a small spine or "radicle," perhaps from 1-20th to 1-10th of an inch in length, as in *Diplograpsus Whitfieldii*, Hall, *D. angustifolius*, Hall, most specimens of *D. pristis*, His. (fig. 9), and some examples of *Climacograpsus teretiusculus*, His. (fig. 8, *f*). Sometimes, however, it forms a long cylindrical fibre, extending below the proximal end of the frond to a distance of an inch or more, as in *Diplograpsus pristini-formis*, Hall, and many specimens of *Climacograpsus teretiusculus*, His. (fig. 8, *a* and *b*). There is, however, a well-marked sub-group of the *Diplograpsi*, comprising *D. cometa*, Gein. (fig. 10, A), *D. palmeus*, Barr. (fig. 11, B), and *D. acuminatus*, Nich. (fig. 10, B), in which no extension of the

Fig. 10.



A, *Diplograpsus cometa*, Gein.; B, *Diplograpsus acuminatus*, Nich., slightly enlarged from specimens from the Upper Llandeilo Shales of Dumfriesshire. (Original.)

axis beyond the proximal end of the frond appears to be ever present—the base of the polypary being formed by the coalescence of the greatly-lengthened first pair of cellules into a more or less blunt process.

It has been stated (Barrande, Grapt. de Bohême, p. 4, and Hall, Grapt. Quebec Group, p. 22) that in some of the forms referable to the genus *Diplograpsus* and *Climacograpsus* the solid axis loses its form of a cylindrical fibre, and is present in the shape of "a thin, flat, apparently double plate, extending across the entire transverse diameter of the tube." This was at one time believed by myself, but an examination of a large number of specimens preserved in relief has fully satisfied me of its incorrectness. The transverse double plate here spoken of as dividing the frond of the diprionidian Graptolites into two vertical compartments is really present, but it is in truth the partition formed by the union of the two unicellular stipes which together make up the compound polypary. These stipes are united back to back (fig. 8, *g*), and their dorsal walls coalesce to form a median septum, which in some specimens is readily separated into its two component laminae. The solid axis is present in its usual form as a cylindrical fibre, and it runs between the two laminae of the septum in the middle line. The edges of the septum appear on the surfaces of the frond in the form of two impressed lines or grooves, which may be straight, slightly undulating, or strongly bent from side to side, so as to correspond to the cellules. These lines must be carefully distinguished from the true solid axis, and, as already remarked, I propose to term them the "sutures."

In some *Diplograpsi*, in place of, or in addition to, the solid axis, or by some modification of the ordinary structure of this, there is an extraordinary vesicular body placed at the distal end of the frond. This occurs as an occasional phenomenon in some examples of *Diplograpsus pristis*, His., *D. palmeus*, Barr. (fig. 11, B), and *D. folium*, His. (fig. 11, C and D). In *D. vesiculosus*, Nich. (fig. 11, A), however, this distal vesicle is not only constantly present, but attains a great degree of development. In this species the centre of the frond is seen to be occupied

by a broad axial tube, which runs its entire length, gradually widening distally, and ultimately expanding into a fusiform vesicle of considerable size, the margins of which are formed by a strong filiform fibre. The functions of this vesicle are quite unknown; but there is every reason to think that it is truly formed by an expansion of the central tube, which, as I have shown, probably occupies the centre of the solid axis. This is particularly well shown in specimens such as *D. folium* (fig. 11, C), in which the axis is actually seen to pass beyond

Fig. 11.



A, *Diplograpsus vesiculosus*, Nich., nat. size, showing the axial tube, terminating in a fusiform distal vesicle; B, *D. palmeus*, Barr., slightly enlarged, showing a distal vesicle; C, *D. folium*, His., showing a very narrow distal vesicle formed by an apparent dilatation of the axis; D, Another specimen of the same, enlarged, showing a larger and apparently double vesicle. All from the Upper Llandeilo Shales of Dumfriesshire. (Original.)

the frond in its usual form as a cylindrical fibre, and then to expand afterwards into a vesicle. The presence of this vesicle, therefore, in species like *D. palmeus* and *D. pristis*, lends strong support to the view that the solid axis is truly hollow. The vesicle itself thus becomes a less anomalous structure, if we regard it as formed by an expansion of a tube which is normally present in the axis.

In the genus *Phyllograpsus*, according to Hall, the solid axis "is composed of four slender flat laminæ." As, however, the frond in this genus is composed of four simple unicellular stipes, united along their non-celluliferous margins, it becomes probable that the laminæ above spoken of are not the true solid axis, but are really the internal walls of these stipes, corresponding with the median septum of the diprionid species.

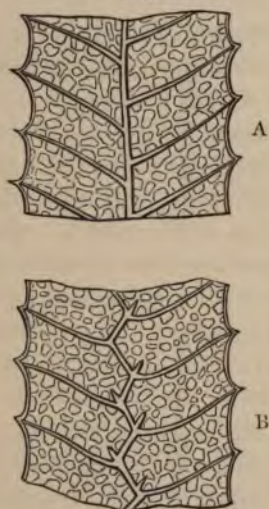
In the genus *Retiolites*, Barr., or rather in the forms generally referred to this genus, it is difficult to say positively what is

the true state of things as regards the solid axis, and I shall discuss this question more fully in speaking of the genus. If we restrict *Retiolites* to the so-called *R. Geinitzianus*, Barr., as is at present safest, we still cannot speak positively as to the presence or absence of a solid axis. By Barrande, who originally founded the genus, it is asserted that no solid axis is present in *R. Geinitzianus*, and many specimens certainly show no traces of such a structure. Still some specimens of even this species show indications of what must almost certainly be a delicate solid axis, or what could only otherwise be the edge of the vertical septum dividing the frond—a structure which is equally absent, according to the description given by Barrande. It is not at all impossible, however, but that there is a solid

axis placed excentrically, so as to be only visible in some views of the frond; as, indeed, is believed by Geinitz.

In the *Retiolites venosus* of Hall (fig. 12) it is asserted that

Fig. 12.



A, View of *Retiolites venosus*, Hall, from the exterior, showing the external axis and cell-partitions. B, Another view of the same from the interior, showing a zig-zag axis, with cylindrical processes extending to the margin, and short, apparently broken, processes directed obliquely upwards. Enlarged nine diameters. (After Hall.)

the frond possesses *two* axes—one “strong excentric or sub-exterior axis, which is nearly direct,” and another undulating or zig-zag axis (fig. 12, B), “to which the cell-divisions of one side are attached.” This structure is wholly anomalous, and this species certainly cannot be retained in the same genus with *Retiolites Geinitzianus*, Barr.

In the *Retiolites ensiformis* of Hall, from the Quebec Group of Canada, there is a very distinct axis on one side of the stipe, and the cell-partitions are apparently attached to this. It is probable, however, that this form cannot be retained in the genus *Retiolites*.

In the genus *Trigonograpsus*, Nich., represented by a single species from the Skiddaw Slates, there is a strong undulating or zig-zag solid axis, to which the cell-partitions are attached, and which is probably excentric in position. It is obvious, however, that in *Retiolites* (?) *venosus*, Hall, *Retiolites* (?) *ensiformis*, Hall, and *Trigonograpsus lanceolatus*, Nich., we have an axial structure which is only to a limited extent comparable with the solid axis of the typical Graptolites. It is obvious, namely, that in these three species the so-called axis is truly within the polypary, and also that it actually has the cell-partitions attached to it. It is certain, on the other hand, that in the great majority, if not in all, of the ordinary Graptolites, the solid axis is truly *outside* the polypary; whilst, with one doubtful exception, it never has any connection with the cell-partitions.

It only remains to be added that there are some genera in which the presence of a solid axis has never been satisfactorily shown, though in these cases we have forms which differ considerably from the typical Graptolite in many other important respects. Thus, no solid axis has ever been demonstrated as present in the genera *Dictyonema*, *Dendrograpsus*, *Callograpsus*, and *Ptilograpsus*; and, indeed, it would seem very probable that this structure is truly wanting. This

Fig. 13.



Trigonograpsus lanceolatus, Nich., showing the zig-zag axis to which the cell-partitions are attached. Enlarged from a specimen from the Skiddaw Slates. (Original.)

peculiarity, conjoined with others of scarcely less importance, would lead to the belief that these genera belong to a peculiar group of the *Graptolitidæ*, or, more probably, that they are referable to an altogether different sub-class.

II. THE COMMON CANAL.—As already defined, the "common canal" is the space formerly filled with cœnosarc of the colony, from which the various zooids are successively budded forth. In specimens of the simple monoprionidian Graptolites, when preserved in relief, the common canal can readily be shown to be a continuous tube placed at the back of the frond, and enclosed by a chitinous envelope or "periderm." On one side, the common canal is supported by the solid axis, which runs outside of the periderm; and on the other side it gives origin to the cellules, or rather to the zooids contained in the cellules. In much-compressed specimens of the simple unicellular species, the common canal is merely recognisable as a continuous vacant space, running between the solid axis and the bases of the cellules, along the entire length of the latter (fig. 4, B).

In the ordinary diprionidian forms constituting the genera *Diplograpsus* and *Climacograpsus*, the structure of the common canal is not essentially different from the above—at any rate, in the majority of cases. In these genera, as already shown, the frond usually consists of two simple stipes placed back to back, and separated by a vertical septum formed by the coalescence of their dorsal walls. Of necessity, therefore, there exist *two* common canals in these forms, one for each of the celluliferous stipes which compose the frond. The structure of these, however, differs in no respect from that of the common canal of the monoprionidian forms.

In *Retiolites Geinitzianus*, Barr., however, it would appear from the researches of Barrande and Geinitz that no such vertical septum exists dividing the two celluliferous halves of the frond. It is asserted, on the other hand, that there is but a single common canal or cœnosarc, from which the cellules are budded forth as a single row on each side.

In *Retiolites* (?) *venosus*, Hall, *R.* (?) *ensiformis*, Hall, and *Trigonograpsus lanceolatus*, Nich., there are also two rows of

cellules, but the cell-partitions are certainly attached to an internal axis. In these species, therefore, we must either suppose that there is a single central common body with an *excentric* axis, or we must believe that the structure is something essentially different to that of all the ordinary Graptolites. The former supposition appears on theoretical grounds to be the most probable, and it is to a great extent borne out by the evidence at present in our hands.

In *Phyllograpsus*, Hall, the frond is apparently formed by the coalescence back to back of four simple monopronidian stipes; and it is inferred by Hall, with great probability, that there is "a slender common canal at the base of each range of cellules."

In several of the complex, branching Graptolites, such as those constituting the genera *Dichograpsus*, Hall, and *Cænograpsus*, Hall (= *Helicograpsus*, Nich.), the common canal does not give off cellules throughout its entire extent. In the *Dichograpsi* the basal or proximal portions of the cœnosarc are simply enclosed in a continuous periderm, and they constitute what I shall afterwards speak of at length as the "funicle." It is sufficient here to point out, as noticed by Hall, that these non-celluliferous portions of the cœnosarc correspond with those portions of the cœnosarc of the Hydroid Zoophytes which are either wholly destitute of buds, or which give origin to branchlets in place of ordinary "hydrothecæ." This analogy is better exhibited in the genus *Cænograpsus*, Hall. In this singular form (fig. 14) "there is a long slender rachis or tubular body, destitute of cellules except at its two extremities, and apparently consisting of a solid axis and a common canal, from which originate, at regular intervals, simple small stipes with solid axis, common canal, and cellules." (Hall, Grapt. Quebec Group, p. 23.)

Fig. 14.

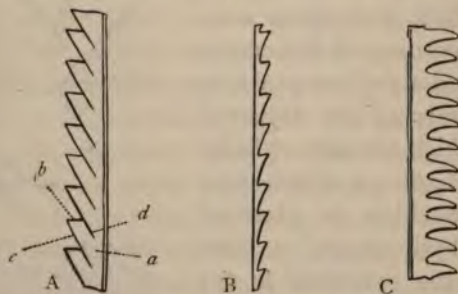


Cænograpsus (Helicograpsus) gracilis, Hall, restored from specimens from the Upper Llandeilo Shales of Dumfriesshire. (Original.)

III. THE CELLULES.—As before remarked, the “cellules” or “calyces” are the little chitinous cups which formerly contained the nutritive zoöids of the Graptolite colony, and which, therefore, correspond with the “hydrothecæ” of the living Sertularian Zoophytes. The cellules are produced by budding from the common canal or cœnosarc; and in most forms the cœnosarc gives origin to the cellules on one side only. This is, of course, the case with all the simple or “monoprionidian” species, in which no more than one row of cellules is present. As already shown, this is also truly the case in most of the “diprionidian” species, since there is really a common canal appropriated to each of the rows of cellules which together constitute the frond. In *Retiolites*, however, it would seem that the cœnosarc gives origin to two rows of cellules, one on each side; though even in this case the phenomenon cannot be said to be free from doubt.

Theoretically, each cellule may be regarded as a cylindrical tube, possessing in longitudinal section four borders (fig. 15, A). Of these the “inner” border is not defined, as it forms the base of the cellule, and rests upon the common

Fig. 15.



Diagrams of cellules. A, Fragment of *Graptolites sagittarius*, His.; B, Fragment of *G. Nilssoni*, Barr.; C, Fragment of *G. Sedgwickii*, Portl. *a*, Inner margin of cellule; *b*, outer margin; *c*, inferior margin; *d*, superior margin.

canal, the “outer” border (*b*) forms the cell-mouth; the “inferior” margin (*c*) is that which bounds the cellule proximally, or on the side which looks towards the base of the

Graptolite; and the "superior" margin (*d*) is that which forms its distal limit. In many species, as in *Graptolites sagittarius*, His. (fig. 15, A), all these four borders are actually present. In some cases, however, as in *G. Nilssoni*, Barr. (fig. 15, B), and *G. discretus*, Nich., the superior margin of the cellule may be said to be practically absent; since in these forms the cellules are triangular, and the common canal is the limit along both the inner and superior margins. In others, again, as in *G. Sedgwickii*, Portl. (fig. 15, C), the cellule terminates in a pointed apex, so that the outer margin can hardly be said to form a distinct line.

In the great majority of the Graptolites, the cellules overlap one another along a portion of their length (as seen in fig. 15, A), leaving only the outer portion free, the parts in contact being more or less completely amalgamated, though theoretically distinct. Great variations, however, exist in this respect, and I may notice the more important of these.

In the greater number of forms, the condition of parts agrees with what is seen in *G. sagittarius* (fig. 15, A). Each cellule, namely, is a sub-cylindrical tube, inclined to the axis with a given degree of obliquity, resting by its base or inner margin upon the common canal, and terminating at its apex or outer margin in an open aperture or "cell-mouth." The cellules are arranged in a vertical series one above another, and their lateral margins or surfaces are consequently free. The cellules, however, are close together at their origin, and each, therefore, is partially concealed by the cellules immediately above and below, but to a different extent. Above, each cellule is in contact with the next cellule in the series along its whole length; so that the whole of the "superior" margin of the cellule is concealed. Below, on the other hand, each cellule is only in contact with the cellule immediately beneath along the inner portion of its length, so that the outer portion of the "inferior" margin is free, and only the inner portion is overlapped. It follows from this that the superior margin of each cellule must be considerably shorter than the inferior margin; and it follows also that nothing more of the cellule is free than the outer portion of

the inferior margin of the cellule and its mouth. As already said, it seems that the walls of the cellules, or "cell-partitions," are coalescent, where in contact; but it is not difficult to show that the contiguous portions are really distinct, as in theory they must be.

In some members of the genus *Graptolites*, such as *G. Nilssoni*, Barr. (fig. 15, B), the cellules, on the other hand, do not overlap one another at all, but are completely free. Each cellule is triangular in shape, and the "superior" margin of the cellule is, strictly speaking, absent.

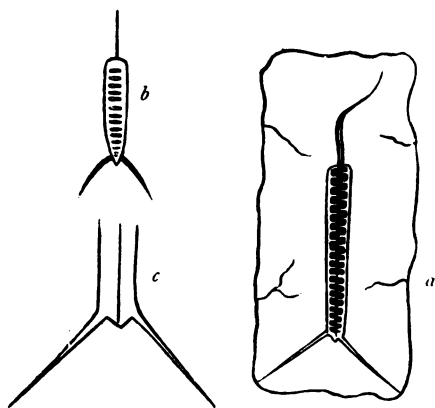
In *Graptolites Sedgwickii*, Portl. (fig. 15, C), *G. lobiferus*, McCoy, and *G. priodon*, Bronn, the cellules are never to any extent amalgamated by any portion of their walls. In the first and second of these the cellules are not in contact at all, or only to an extremely limited extent at their bases; and in *G. priodon*, though the basal portions of the cellules touch, they do not cohere by the cell-partitions.

In the majority of the *Diplograpsi*, the cellules overlap one another partially, much as in *Graptolites sagittarius*. In some forms, however, such as *D. palmeus*, Barr. (fig. 4, D), the cellules overlap for the greater part of their length, and this is still more marked in *D. folium*, His. (fig. 4, E). In other cases, as in *D. tamariscus*, Nich. (fig. 4, C), the cellules are almost wholly free, and only overlap to a very limited extent.

In the genera *Climacograpsus* and *Dicranograpsus* we have quite a peculiar type of cellule. In these forms the cell-mouths are situated in hollows, which look as if they were scooped out of the margin of the polypary. The cell-mouths, therefore, are placed below, or internal to, the general boundary of the frond (see fig. 8, *a*), and they are not placed at the end of tooth-like "denticles," as they are in the nearly-allied genus *Diplograpsus*. The result of this is, that when the frond is viewed laterally, either in much-compressed specimens or in section (fig. 8, *a*), the cell-apertures appear as a number of rounded or subquadrate notches, sunk below the general level of the polypary. When, on the contrary, specimens are examined which present us with a view of one of the celluliferous

surfaces of the frond, we find the cell-apertures in the form of elliptical, lunate, or nearly straight fissures, running across the polypary (fig. 16, *a* and *b*). Judging merely from much-

Fig. 16.



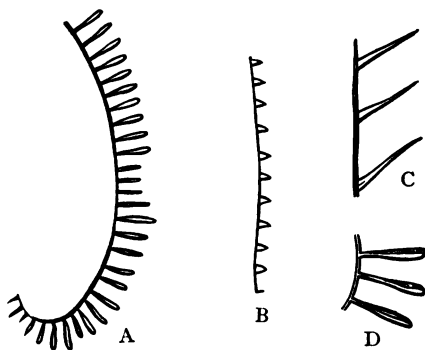
a, *Climacograpsus antennarius*, after Hall, showing the cell-apertures; from the Quebec Group. *b*, Small specimen of the same, from the Skiddaw Slates; nat. size. *c*, Base of another specimen from the Skiddaw Slates, with unusually long basal spines; enlarged.

compressed examples, or from the very common specimens which are merely exhibited in section, it would certainly appear that the cellules in this genus were "excavated" in margins of the frond, and that they were not separated by any distinct cell-partitions. When examined, however, in a state of relief, it becomes at once evident that this is not the case, but that the cellules are bounded by genuine cell-partitions, as in all the ordinary forms. The cellules, however, are so bent that the outer portion of each becomes parallel with the axis of the frond, thus bringing the cell-mouth directly underneath the cellule immediately above (fig. 8, *c*). The foreshadowing of this state of parts may be observed in some of the *Diplograpsi* (e.g., in *D. putillus*, Hall, and *D. tamariscus*, Nich.) As already pointed out, also, this peculiar arrangement of the cellules renders it impossible for any views of the frond to be presented except such as would be called "scalariform" or "semi-scalariform."

In the genus *Retiolites*, the cellules are in contact throughout their entire length (fig. 12), and the same is the case in the genus *Trigonograpsus* (fig. 13). In *Phyllograpsus*, also, the cellules overlap throughout their whole extent, or at most leave the tip of the inferior margin of each cellule free (fig. 18).

Lastly, in *Rastrites* (fig. 17) not only are the cellules free throughout their entire extent, but they are invariably separated from one another by more or less evident intervals

Fig. 17.



A, *Rastrites peregrinus*, Barr., from the Mudstones of the Coniston Series, enlarged. B, *Rastrites capillaris*, Carr., from the Upper Llandello Shales of Dumfriesshire, enlarged. C, Fragment of *Rastrites Linnei*, Barr., from the Coniston Mudstones, enlarged. D, Fragment of *R. peregrinus*, greatly enlarged, showing the impressed line running up the centre of each cellule. (Original.)

or spaces. The common body, in other words, does not produce buds continuously, but only at fixed points separated from one another by definite interspaces. The cellules, also, in this genus, have in most cases distinctly the form of cylindrical tubes, which in compressed examples exhibit an impressed line, running up their centre, and due to their being crushed (fig. 17, D).

As regards the *cell-apertures*, we have to notice that not only are the cellules inclined to the axis of the frond at an angle of obliquity peculiar to each species, but the cell-mouths have a fixed direction as regards the axis of the cellule. In

some cases the cell-apertures are rectangular to the axis of the cellule; but, more commonly, the cell-mouth forms an acute angle with the cell. Rarely the cell-mouth makes an obtuse angle with the axis of the cellule. The form of the cell-mouth, when it can be determined, is usually circular; but in some cases it is nearly quadrangular (e.g., in *Retiolites Geinitzianus*, according to Barrande). In a very large number of species, belonging to several genera, the inferior edge of the cell-mouth is prolonged into a spine or mucronate extension (fig. 19), which is apparently produced by a continuation, beyond the general surface, of the inferior cell-partition.

Fig. 18.



Phyllograpsus angustifolius. Quebec Group.
(After Hall.)

Fig. 19.



Fragment of *Graptolites* (?) *latus*, M'Coy, from the Skiddaw Slates, showing the mucronate extensions of the lower edges of the cellules. Probably this is really a broken stipe of one of the *Dichograpsi*. (Original.)

The *position* of the cell-mouth, as regards the entire colony, depends upon the form of the cellules in each species; and this is so variable, that I need not discuss this question here. It is sufficient to say that in the great majority of instances the cellule is so placed that the contained zoöid could be protruded in direction away from and obliquely ascending as regards the axis of the polypary; the mouth of the zoöid being, therefore, directed upwards. In other instances, as in *Diplograpsus tamariscus*, Nich. (fig. 4), the mouth of the cellule is directed straight upwards, parallel with the axis of the frond. In other cases, again, as in *Graptolites priodon*, Brönn, the doubtfully distinct *G. Clintonensis*, Hall, and other allied forms, the cellule is so bent that the mouth looks

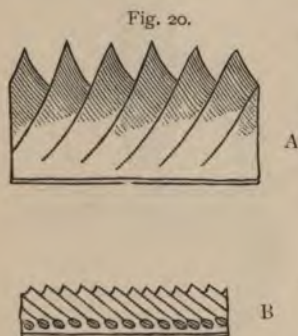
directly downwards towards the proximal end of the polypary, or it is directed downwards and outwards.

IV. SURFACE-MARKINGS AND ORNAMENTATION OF THE POLYPARY.—As regards the surface-markings of the polypary in the Graptolites there is little to be remarked. In a great many species there are found parallel curved striæ running parallel with the mouths of the cellules, and extending for a greater or less distance towards the base (fig. 20, A). These are doubtless lines of growth, marking the periodical

additions made to the circumference of the cellule round its mouth. These lines are seen in several monopronidian species, and some dipronidian forms (e.g., *Diplograpsus palmeus*, Barr., and *D. folium*, His., see fig. 4).

In rare instances, as in *Diplograpsus tamariscus*, Nich. (fig. 4, C), the entire surface of the polypary is covered with fine transverse striæ; and Hall has noticed irregular striation in the stems and branches of *Dendrograpsus*, *Callograpsus*, and *Dictyonema*.

In several of the Graptolites of the Quebec Group, Professor Hall



A, Fragment of *Didymograpsus patulus*, Hall, enlarged to show the lines of growth of the cellules.
B, Fragment of *Didymograpsus nitidus*, Hall, enlarged to show the pustules at the bases of the cell-walls. (After Hall.)

has observed minute pustules at the bases of the cell-partitions (fig. 20, B). I have noticed similar pustuliform elevations at the bases of the cellules in *Didymograpsus anceps*, Nich., and in a few specimens of *Graptolites Sedgwickii*, Portl.; but I am unable to offer any explanation of their use and nature, unless, as hinted by Hall, they be the cicatrices where "ovarian capsules" were at one time attached.

In a new species from the Coniston Flags of the North of England, which I propose to call *Graptolites vomerinus* (fig. 21), there is a peculiar reniform elevation of the common body at the point of origin of the superior cell-wall in every cellule, the elevation extending round the base of the cell-

partition into the bottom of the cellule next above. As in the preceding case, however, I am unable to offer any hypothesis as to the nature of these peculiar structures.

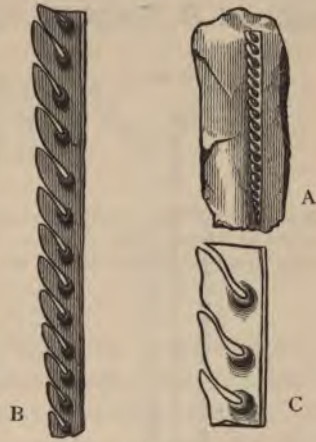
In the forms which are truly referable to the genus *Retiolites*, Barr., the surface of the frond exhibits a most remarkable network of delicate lines enclosing rounded or polygonal spaces. In some, at any rate, of the forms ordinarily referred here, if not in the type-form, *R. Geinitzianus*, this appearance is, however, no mere surface-marking. In the forms, namely, which have been described as *Retiolites venosus*, Hall (fig. 12), and *R. perlatus*, Nich., these superficial reticulations appear to be merely the surface-indications of an extraordinary system of interlacing fibres which ramify in the interior of the frond. In fact, a specimen of *Retiolites*, discovered in the

Coniston Flags of Brathay, Westmoreland, by Mr Talbot Aveline of the Geological Survey, would seem to indicate that the reticulated surface ordinarily seen in specimens of this genus is not the true exterior of the polypary, but that it is covered by a continuous and entirely smooth chitinous periderm.

As regards the *ornamentations* of the polypary of the Graptolites—if we may use this term for structures of whose use we are absolutely ignorant—a great deal might be said; but I shall leave details on this subject until I come to deal with the specific forms separately, merely noticing here a few of the more striking appearances:—

The most noticeable structures which may be considered under this head, are the spines or mucronate processes

Fig. 21.



A, Fragment of *Graptolites vomerinus*, Nich., slightly enlarged. B, Portion of another individual of the same, greatly enlarged. C, Fragment still further enlarged. (Original.)

with which a large number of Graptolites are furnished. In the great majority of cases these processes (fig. 23) are to be regarded merely as extensions of the inferior margins of the cellules beyond the cell-mouths. In most cases each cellule has only one such process (as in *Diplograpsus mucronatus*, Hall, and *D. Whitfieldii*, Hall), but sometimes each cellule

Fig. 22.



Diplograpsus pristis, His. Enlarged.
Showing lateral processes flank-
ing the radicle. (After Hall.)

Fig. 23.



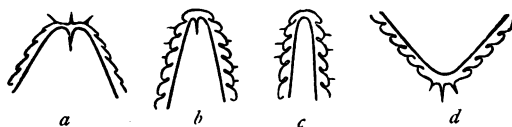
Diplograpsus Whitfieldii, Hall. En-
larged. Showing spines proceed-
ing from the cell-mouths.

has two spines (as in *Diplograpsus quadrimucronatus*, Hall, and *D. bimucronatus*, Nich.) Ordinarily the spines are short and rigid, but in the last-mentioned species they are long and slender, and they attain an even greater length in *D. armatus*, Nich. In a few cases, the spines seem to be developed from the middle of the inferior margin of the cellules, and in others it would seem as if the superior margin of the cellule was

developed into a spine ; though, I confess, I think this very questionable.

Lastly, it should be mentioned that the first two cellules of the frond not uncommonly develop spines, even in species in which all the other cellules are spineless. This is well seen

Fig. 24.



a, base of *D. flaccidus*, Hall ; *b*, base of *D. anceps*, Nich., showing the internal radicle ; *c*, base of another example of *D. anceps*, in which there is no radicle ; *d*, base of *D. divaricatus*, Hall, showing the radicle with its two lateral spines. All enlarged.

in *Didymograpsus flaccidus*, Hall (fig. 24, *a*), in which each of the first two cellules carries a spine ; and a central spine is developed between them, opposite to the true "radicle." In most cases, however, as in *Didymograpsus divaricatus*, Hall (fig. 24, *d*), and in *Diplograpsus pristis*, His. (fig. 22), the spines which arise from the bases of the first pair of cellules flank the "radicle," and they are occasionally developed to a perfectly astonishing length (as in *Climacograpsus antennarius*, Hall, fig. 16).

CHAPTER V.

NATURE AND FUNCTIONS OF THE BASE IN THE
GRAPTOLITES.

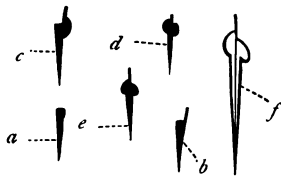
I. THE RADICLE AND BASAL PROCESSES. — At the base, in the great majority of Graptolites, if not in all, there is found a small slender pointed process, to which Hall has applied the name of “radicle” or “initial point.” In the youngest forms of Graptolites known to us the radicle is always a well-marked feature, and in some cases the entire organism consists at first of nothing more than a little trian-

gular “mucro,” which is, indeed, the “radicle” (fig. 25). The term “initial point” is, therefore, a very appropriate one, since this is truly the starting-point of the entire polypary.

According to Hall, the “radicle” is defined as the commencement of the *solid axis*. It seems certain, however, that the radicle is not composed *solely* of the solid axis; and it would, indeed, seem that the solid axis is not even the essential element in its composi-

tion. On the contrary, it seems probable that the radicle is to be regarded as the commencement of the *common body* or *cœnosarc*, enclosed in a delicate chitinous sheath; and it does not appear that a solid axis is present in the earliest

Fig. 25.



a, Young Graptolite, consisting of nothing but a little triangular radicle; *b*, another form, in which, in addition to the true radicle, there is a delicate solid axis; *c*, another young form, in which the development of the cellules has commenced. All enlarged greatly. (Original.)

stages of its development. A solid axis, however, always may be recognised at an early period of growth, and it then becomes in most instances the chief, or even the only, element of the "radicle." I shall therefore, in accordance with these considerations, employ the term "radicle" to signify the basal median process which is seen in most Graptolites, whether this consists of the solid axis alone, or of the solid axis along with the common body, or simply of the investing envelope of the latter.

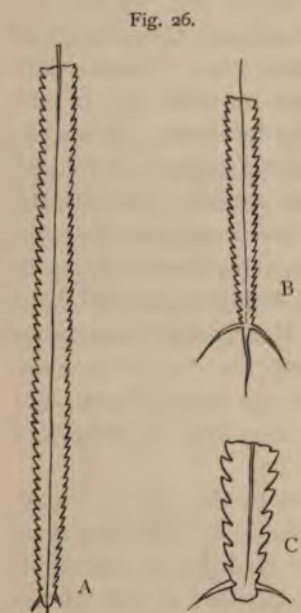
When examined in its younger stages (fig. 25, *a*), the radicle would appear to consist of a corneous tube, broad at one end and tapering gradually to the other. Soon a delicate solid axis appears, placed either on one side of the common body (fig. 25, *b*) or running up its centre. From the broader end of the radicle the primitive cellule or cellules are then developed (fig. 25, *c*); but, as growth proceeds, the radicle generally undergoes more or less important changes, sometimes greatly diminishing in size, sometimes seeming to disappear altogether, and very often being succeeded by a proximal extension of the solid axis alone, which sometimes reaches a very great length. Rarely the radicle is more largely developed in the adult than in the young form; and in some cases it would seem from the first to consist of nothing more than the solid axis.

In the simple monoprionidian forms of the genus *Graptolites*, the base of the adult is rarely exhibited; but when seen, is found to be usually slender and curved (fig. 6), commencing with a long radicle, apparently composed at first of the solid axis alone, but soon widening out by the addition of the common canal. In some cases (as seen in fig. 6, B and D) the radicle is extremely long, and consists solely of the solid axis, either throughout, or for the greater part of, its length. The first cellules are much smaller than those of the adult portion of the frond, and their characters are often wholly different. In some members of the genus *Graptolites*, as in *G. priodon*, Bronn (fig. 7, A), *G. colonus*, Barr. (fig. 4, A), and *G. vomerinus*, Nich. (fig. 21, C), the commencement of the frond is not curved, but is straight, and the radicle is apparently only a short

blunt process, with an additional lateral spine in *G. colonus*. In none of the forms included in this genus are there any phenomena which would lead to the belief that the radicle served at any time as a process of attachment. Indeed, in those in which the base is curved, and still more in those in which the frond is coiled into a spiral, all the coils of which lie in one plane, the mere position of the radicle seems sufficient wholly to negative this supposition.

In the genus *Rastrites*, Barr., the nature of the base is not known, no example having hitherto been discovered in which the proximal extremity is exhibited. Judging from analogy, however, there is every reason to think that the base was slender and curved, as in *Graptolites sagittarius*, His. It is, therefore, most probable that *Rastrites* could not have been at any time attached by its base.

In the bi-celluliferous forms constituting the genera *Diplograpsus*, *Climacograpsus*, and *Dicranograpsus*, the nature of the base is subject to many interesting and important variations. In most of the commoner *Diplograpsi*, and in the genus *Dicranograpsus*, the base is constituted by three processes or spines (figs. 22, 23, 26), of which the central one is the true continuation of the solid axis, and is, therefore, the true "radicle," whilst the two lateral spines appear to spring from the bases of the first pair of cellules. In all these cases the true central radicle appears to consist of the solid axis alone; and its length is



A, *Diplograpsus pristis*, His., slightly enlarged, showing the normal condition of the base; B, Another example of the same, slightly enlarged, showing a long radicle and long lateral spines; C, Another of the same, enlarged, showing lateral spines, succeeded proximally by a small bulb, but showing no true radicle. (Original.)

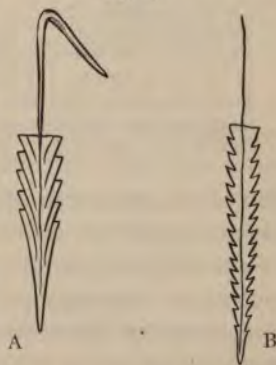
very different in different species, or even in different indi-

viduals of the same species. Thus, in all the ordinary examples of the common *Diplograpsus pristis*, His., the radicle is very minute, and so are the lateral spines also (fig. 26, A). There exists, however, a well-marked form of this species (fig. 26, B), in which all the three basal processes are enormously developed, the "radicle" especially so. Again, in *Diplograpsus Hopkinsoni*, Nich., the "radicle" is extremely minute, or even seemingly wanting, whilst the lateral spines are developed into long setiform, straight, or curved processes. In none of the above-mentioned forms, however, is there any evidence tending to show that the radicle can have served as a point of attachment for the frond, seeing that it is either too small and weak to have performed this office, or it is outflanked by the greater length of the lateral processes.

In a second group of the *Diplograpsi*, of which *D. pristini-formis*, Hall, and some specimens of *D. tamariscus*, Nich., may be taken as examples, there are no lateral processes, and the radicle consists of a long proximal extension of the solid axis. In these, therefore, the radicle might possibly have served as a process of attachment, though there is no evidence to show that this was the case.

In a third group of the *Diplograpsi*, comprising *D. cometa*, Gein. (fig. 27, A), *D. palmeus*, Barr. (fig. 4, D), *D. folium*, His. (fig. 4, E), *D. vesiculosus*, Nich., and *D. acuminatus*, Nich. (fig. 27, B), there is no proximal extension of the solid axis, and there is, therefore, no true "radicle" in Hall's sense of the term. There is, however, a basal process apparently formed chiefly, if not entirely, by a great elongation of the first pair of cellules. This process is tapering and triangular in shape, and ends proximally in a blunt extremity, which is sometimes slightly bulbous, and which does not appear ever to

Fig. 27.

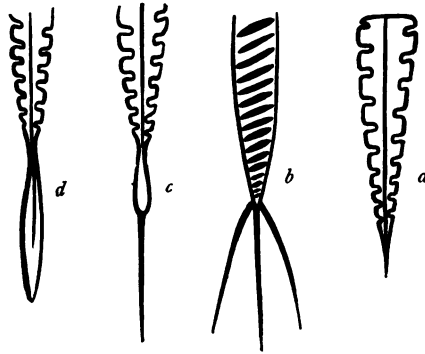


A, *Diplograpsus cometa*, Gein., enlarged. B, *D. acuminatus*, Nich., enlarged. (Original.)

exhibit any extension of the solid axis alone. The nature of the rounded, and sometimes truncated, base in these forms is such as to show plainly that the organism could not have been attached at this point.

In the genus *Climacograpsus*, Hall, comprising forms nearly allied to the *Diplograpsi*, the exact nature of the base varies very much, even within the limits of the same species. In the commonest and best known species—viz., *C. teretiusculus*, His.—there appears to be normally a single basal process or “radicle,” composed of a longer or shorter proximal exten-

Fig. 28.



- a*, Base of the common form of *Climacograpsus teretiusculus*, with a short radicle : Coniston Mudstones. *b*, Base of the same, showing a long median radicle and two long lateral spines : Upper Llandeilo, Dobb's Linn, near Moffat. *c*, Base of the same, showing the commencement of the radicle enveloped in a sheath : Upper Llandeilo, Hart Fell, near Moffat. *d*, Base of the same, showing the radicle swelling out below into a species of vesicular dilatation : Upper Llandeilo, Garple Linn, near Moffat. All much enlarged. (Original.)

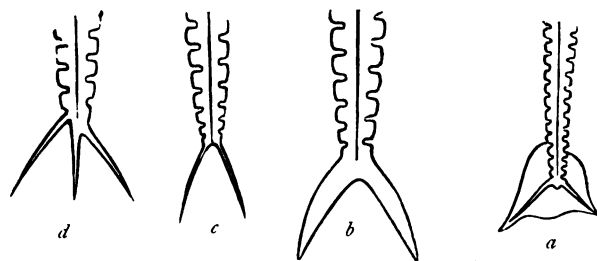
sion of the solid axis alone (see fig. 8, *a* and *b*, and fig. 28, *a*). In some cases this process is very short, but in others it attains an extraordinary length. In some other forms of the same species, as originally pointed out by Mr Carruthers, the commencement of this radicular extension of the axis is enveloped in a kind of sheath derived from the polypary (fig. 28, *c*). In another well-marked variety, in addition to the true radicle, there are developed two long flanking spines, which may be as long as the radicle itself (fig. 28, *b*). Lastly, in another variety the basal process is developed into an elongated,

elliptical dilatation (fig. 28, *d*), the exact nature of which is obscure.

In *Climacograpsus antennarius*, Hall, there is an extremely short radicle, often a mere tubercle, flanked by two lateral spines of extraordinary length (fig. 16).

In *Climacograpsus bicornis*, Hall, the normal condition of the base is for there to be two longer or shorter lateral spines, with no true central radicle (fig. 29, *c*). In some cases, however, a central radicle is asserted by Hall to be present (fig. 29, *d*). In another extremely well-marked and interesting variety of this species, the base is formed by a vesicular

Fig. 29.



a, Base of *Climacograpsus bicornis*, after Hall, showing a basal disc or bulb; magnified two diameters. *b*, Base of the same, showing an imperfect basal crescentic disc; enlarged, from a specimen from the Llandeilo Shales of Glenkiln Burn, Dumfriesshire. *c*, Base of the ordinary form of *C. bicornis* in Dumfriesshire, without a central radicle; enlarged. *d*, Base of the same, after Hall, showing the lateral spines flanking a central radicle.

dilatation or "disc," which may be crescentic in shape, but which sometimes appears to extend distally upon the lower cellules (fig. 29, *a* and *b*). This singular structure, as we shall subsequently see, can hardly differ in kind from the corneous disc, which is present in several species of the complex monoprionidian genera, *Dichograpsus* and *Tetragrapsus*.

In none of the *Climacograpsi* is there any reason to suppose that the frond was attached by its base; and in some forms, such as *C. antennarius* and *C. bicornis*, this seems clearly impossible.

In *Phyllograpsus*, which may be regarded as in many respects merely a double *Diplograpsus*, the nature of the base

varies, and great doubt may reasonably be entertained as to the existence of a true solid axis. In some of the specimens, however, of *Phyllograpsus typus*, Hall, there is a basal process or radicle of considerable length (Hall, Grapt. Quebec Group, Pl. XV. figs. 1 and 2); but the thickness and triangular form of this would lead to the belief that it is not constituted by the solid axis. In *P. angustifolius*, Hall (fig. 18), and in *P. Anna*, Hall, on the other hand, this basal or radicular process does not exist, and the base is simply rounded off. In none is there any evidence that the frond was ever attached by its base.

In the genus *Didymograpsus* (fig. 30), comprising those Graptolites in which the frond consists of two simple mono-

Fig. 30.

*Didymograpsus divaricatus*, Hall. Enlarged. (Original.)

prionidian stipes diverging from an initial point, a radicle is almost invariably present. The length, however, of the radicle varies extremely, sometimes being a mere pustule, and at other times being apparently altogether wanting, whilst it may reach a length of over a line. In form, the radicle is more distinctly triangular than is the case in the majority of Graptolites; but it is not certainly determinable what elements enter into its composition. It seems, however, never to consist merely of an extension of the solid axis, as is certainly the case in some of the diprionidian forms. As regards the functions of the radicle in this genus, some forms—such as *D. flaccidus*, Hall, and *D. anceps*, Nich. (fig. 24)—show plainly that the frond was not attached at this point; since the two stipes are bent backwards, and the radicle is placed

on the *concave* side of the polypary. In other forms, however, the radicle is on the convex side of the frond, and might therefore, as far as its position goes, have served as an organ of attachment.

Lastly, in some forms, as in *Didymograpsus sextans*, Hall (fig. 31), there does not appear to be a true median radicle; but there are two minute lateral processes which seem to spring from the bases of the first pair of cellules. These processes probably correspond with the lateral spines which flank the radicle in *D. divaricatus*, Hall (fig. 30).

In the genus *Pleurograpsus*, Nich., the base is provided with a simple radicle, just like that of a *Didymograpsus*; but the frond is now compound, and is made up of numerous branches which arise from the sides of the primary stipes. In the case of *P. linearis*, Carr.—the only species in which the base has been observed—the radicle is so surrounded by long radiating branches, the terminations of which are not shown, that it is clearly impossible that the frond should ever have been attached at this point.

In the genus *Cyrtograpsus*, Carr., the frond is equally complex, but the base appears to have been rolled up spirally, rendering it impossible for the frond to have been fixed by a radicle.

II. THE FUNICLE.—We come now to a group of complex Graptolites, comprising the genera *Dichograpsus*, *Loganograpsus*, *Tetragrapsus*, *Retiograpsus*, and *Cænograpsus* (= *Helicograpsus*), in which the base is constituted by a non-celluliferous connective process, to which the name of “funicle” has been applied

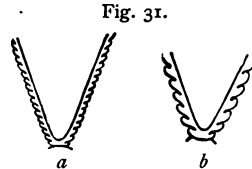


Fig. 31.
Didymograpsus sextans: a, a specimen slightly enlarged and with the cellules partially restored; b, base of the same, enlarged. (Original.)

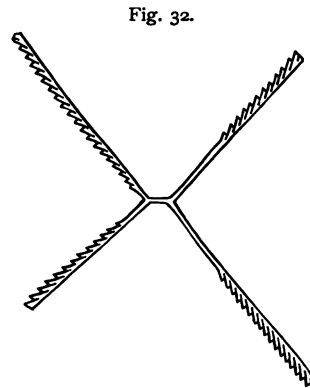
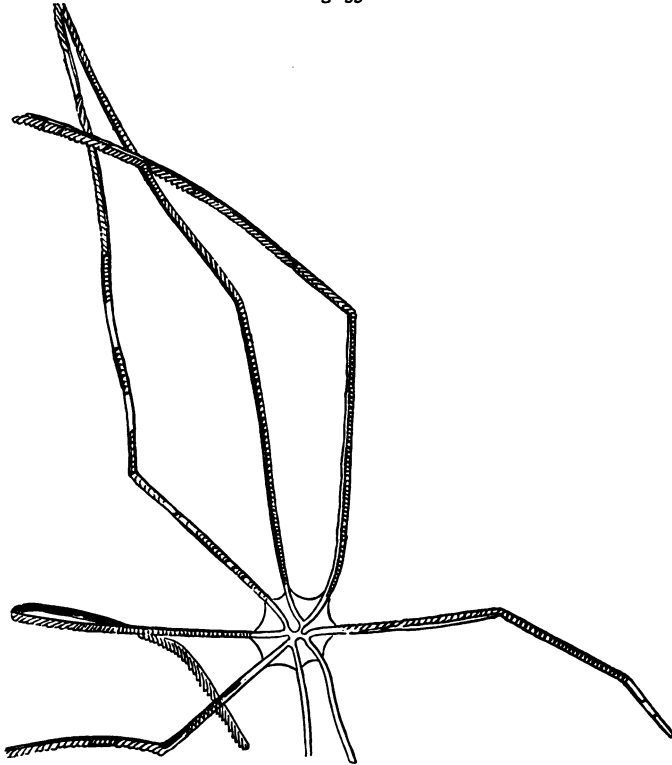


Fig. 32.
Tetragrapsus (*Graptolithus*) *quadribrachiatus*, Hall, showing the “funicle.” (After Hall.)

by Hall. The "funicle" is in all cases the central basal portions of the Graptolite, which consist of the common canal alone, and which are *destitute of cellules*. In other words, the "funicle" (fig. 32) is that portion of the common canal which has no power of throwing out buds. In its simplest forms, as in the *Tetragrapsi* (fig. 32), the funicle

Fig. 33.



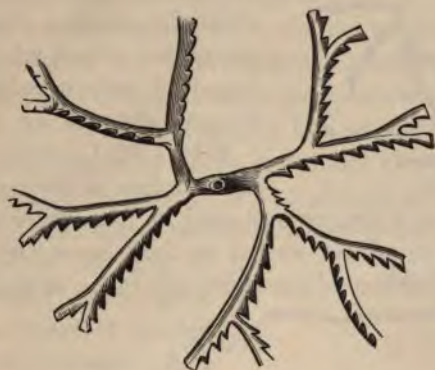
Dichograpsus (Graptolithus) octobrachiatus, Hall. (After Hall.)

consists simply of a non-celluliferous central bar, from the two extremities of which spring the four stipes which compose the frond, two arising from each end.

In the *Dichograpsi*, the funicle (fig. 33) is much more complex, consisting of eight or more divisions, each of which terminates in a single monopronidian stipe. In the majority

of cases, the divisions of the funicle are non-celluliferous, and it is not until we reach its terminal branches that we meet with the cellules. In one species, however (*viz.*, *D. Milesi*, Hall), the cellules are developed, according to Hall, upon all the subdivisions of the funicle, and there is simply a non-celluliferous central bar, as in the *Tetragrapsi* (fig. 34). In

Fig. 34.

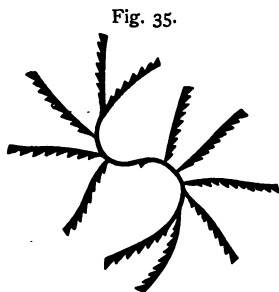
Base of *Dichograpsus* (*Graptolithus*) *Milesi*, Hall. (After Hall.)

Loganograpsus, Hall, the funicle divides into from eighteen to twenty divisions, all of which are at first non-celluliferous, but ultimately terminate in simple monoprionidian stipes.

Lastly, in *Retiograpsus*, Hall, there is a central non-celluliferous funicle, all the divisions of which terminate in diprionidian stipes.

Though usually concealed, a true radicle is found occupying the central point of the funicle, in some cases certainly, and probably in all cases really. When visible, the radicle does not seem to differ in any essential respect from that of the *Didymograpsi*, and in most cases there is clear evidence that it cannot have served as a point of attachment. This is especially manifest in such a form as *Tetragrapsus caduceus*, Salt. (= *T. bryonoides*, Hall), in which the four branches composing the frond are reflexed, so as to form a pyramid or dome, at the apex of which, but on its *inferior* surface, is placed the radicle.

In the genus *Cænograpsus*, Hall (= *Helicograpsus*, Nich.), the funicle is very peculiar, and differs greatly from that of

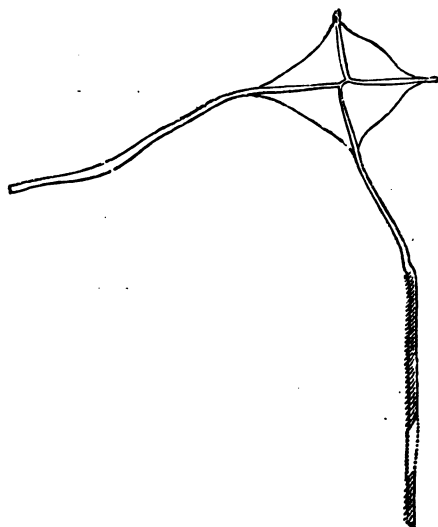


Cænograpsus gracilis, Hall.
Restored.

any of the preceding forms. In this type (fig. 35) the funicle is a long, tubular, non-celluliferous process, the two extremities of which become celluliferous, whilst the intermediate portion gives origin to a variable number of simple mono-prionidian stipes, which are developed at certain points, according to some definite law.

III. THE CENTRAL DISC.—In one species of *Dichograpsus*, several species of *Tetragrapsus*, and in *Loganograpsus*, the divisions of the frond are united at their bases "by a thickened corneous expansion of the same substance as the body of the

Fig. 36.



Central disc of *Tetragrapsus Headi*, Hall, sp. (After Hall.)

Graptolite" (fig. 36). "This appears to be composed of two laminæ, which, at least in the central portions, are not con-

joined, and the space is probably occupied by some softer portion of the animal body" (Hall, Grapt. Quebec Group, 20).

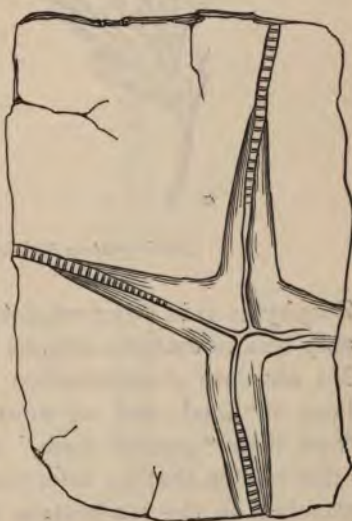
This central corneous disc of the above-mentioned forms doubtless serves to support the frond; but this can at best be but a secondary function. I have compared it with the "float" of the *Physophoridae*, amongst the Oceanic Hydrozoa; and I am still inclined to believe that we have here a relationship of more than mere resemblance.

As already noticed, traces of a similar structure are to be found in certain of the diprionidian Graptolites. This is especially the case with *Climacograpsus bicornis*, in which, as first pointed out by Hall, there is not uncommonly a basal disc or bulb, the shape of which is usually crescentic (fig. 29, *a* and *b*). That this structure is homologous with the disc in the complex forms above noted, can hardly be doubted.

The shape of the disc in the *Tetragrapsi*, *Dichograpsi*, and *Loganograpsi* is mostly approximately circular. It is generally, however, prolonged to a slight extent along each division of the funicle; and in *Tetragrausus alatus* (fig. 37) the substance of the disc is prolonged "along the margins of the stipes, producing an alation."

IV. Before leaving the subject of the nature of the base in the Graptolites, I may notice the structure of this part in the genera *Dictyonema*, *Dendrograpsus*, *Callograpsus*, and *Ptilograpsus*, all at present, though with doubtful propriety, included in the family of the *Graptolitidae*. In all these forms, as in none of the preceding, the structure of the base is such as to support the view that the frond was really

Fig. 37.



Tetragrausus (Graptolithus) alatus, Hall.
(After Hall.)

fixed. Thus, it has been shown by Hall that in such specimens as exhibit the lower portion of the frond (fig. 38), the branches become gradually aggregated, so as ultimately to form a strong rootlike process, resembling the proximal end of the "hydrocaulus" in the Sertularians. (See Hall's figure of *Callograpsus elegans*, Grapt. Quebec Group, Pl. XIX., fig. 2.) The resemblance of these genera to some of the Hydroid

Fig. 38.

*Dendrograpsus Hallianus*, Prout. (After Hall.)

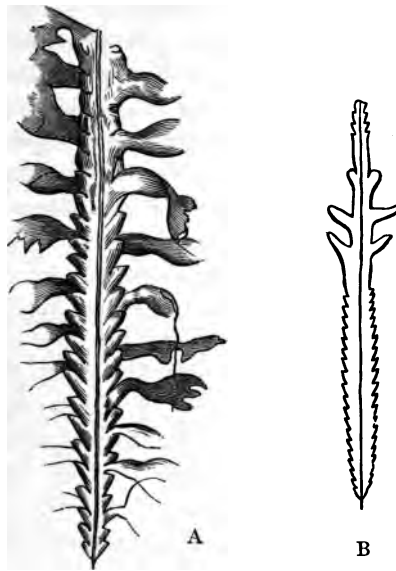
Zoophytes is in other respects so strong that we may reasonably believe that this process was truly a point of attachment. No absolute demonstration of this has, however, hitherto been obtained; and we must admit with Hall that it is only from their "general form," and "from their analogy with other bodies, that we infer that these genera may have been attached to the sea-bottom or to some objects during their growth."

CHAPTER VI.

REPRODUCTION AND DEVELOPMENT.

I. REPRODUCTION.—For obvious reasons, our knowledge of the reproductive process in the Graptolites can never be

Fig. 39.



A, *Diplograpsus pristis*, with reproductive bodies (after Hopkinson). B, *Diplograpsus Whitfieldii*, with reproductive bodies (after Hall). Enlarged.

expected to be complete ; and, in point of fact, it is only of late years that we can be said to have obtained any positive

facts upon this subject. The first contribution to our acquaintance with the reproductive process amongst the Graptolites was made by Professor Hall, who in 1858 described certain examples of *Diplograpsus Whitfieldii* as bearing what he regarded as reproductive bodies or "ovarian capsules." The specimens in question (fig. 39, B) were furnished on both sides with external processes which "first appear as small ovate buds upon the margins, projecting but little beyond the regular cellules, and, becoming enlarged, form elongated sacs with swollen extremities, which are finally dehiscent." In actual structure, these sacs show nothing definite, except that their margins are "limited by a filiform extension resembling the solid axis of a Graptolite." Hall further believes that these sacs were attached to the solid axis of the Graptolite, and he adds that they are traversed by numerous filiform fibres, which "sometimes remain attached to the original stipe after the other parts are separated." I may mention in this connection that it is by no means uncommon to meet with examples of *Diplograpsi* in the Upper Llandeilo Shales of Dumfriesshire in which both margins of the frond are furnished with long ramifying fibres, as in the specimen figured below (fig. 40); and I have no doubt that these are essentially the same as in the specimens described by Hall.

Fig. 40.



Specimen of *Diplograpsus* from the Upper Llandeilo Shales of Dumfriesshire, showing lateral fibres, which are probably the remains of reproductive sacs.

Until lately no *Diplograpsus* carrying bodies similar to those described by Hall had been described or figured by any other observer. Recently, however, Mr John Hopkinson has given an account of a specimen of *Diplograpsus pristis*, His., furnished with reproductive capsules, and I have reproduced his figure of the same (fig. 39, A). The specimen in question is from the Upper Llandeilo Shales of Dumfriesshire, and is described in the 'Annals and Magazine of Natural History,' May 1871. Each side of the frond is provided with a number of somewhat pyriform sacs, the margins of which are formed by a single fibre. "They appear to have been budded

from the periderm at right angles to the hydrothecæ," and their outer limits are ill defined. At the proximal end of the polypary only the lateral fibres which bound the sacs are preserved, and they are sometimes traversed by fibres which extend into the body of the polypary for some distance. From the above, it will be evident that the bodies described by Mr Hopkinson as occurring in *Diplograpsus pristis* differ in no way from those noticed by Hall as occurring in *D. Whitfieldii*; and no doubt can be entertained as to their complete identity.

Long before Mr Hopkinson's discovery, in 1866, I had announced the discovery in the Upper Llandeilo Shales of Dumfriesshire of bodies which I then regarded, and still regard, as being connected with the reproductive process of the Graptolites. These singular bodies, the general forms of which are shown in fig. 41, I compared with the "ovarian capsules" of the Sertularian Zoophytes; and though I did not at that time fully recognise how wide are the differences which separate these two classes of objects, I still think that the comparison was a justifiable one.

The bodies in question (fig. 41) occur in great plenty in the Upper Llandeilo Shales of Dumfriesshire, and I have also detected them not very rarely in the Mudstones of the Coni-

Fig. 41.



Ovarian capsules of Graptolites. *a*, Fragment of shale with several ovarian capsules, natural size. *b*, A single capsule, with an unbroken margin, enlarged. *c*, Another specimen in which rupture has taken place, enlarged. *d*, Another capsule of a different shape. *e*, *f*, *g*, Capsules compressed vertically, enlarged. *h*, A capsule presenting numerous concentric striæ, enlarged. (Original.)

ston Series. They are undoubtedly of the same corneous texture as the Graptolites themselves, and they usually present themselves as glistening pyritous stains. When compressed laterally (fig. 41, *b, c, d*), they appear as oval or bell-shaped bodies provided at one extremity with a prominent spine or mucro; and the larger examples may be as much as from three-tenths to four-tenths of an inch in length, and from one-tenth to two-tenths of an inch in breadth. The great majority of specimens exhibit nothing in the way of definite structure, except that the margins are bounded by a filiform fibre proceeding from the mucro. In some specimens—which are presumably younger than the others—this limiting fibre is continuous round the entire margin of the body, the shape of which is then completely defined (fig. 41, *b*). In the greater number of examples, however,—which are presumably older than the preceding—this limiting fibre appears to have given way opposite to the mucro, and this margin of the body is then quite undefined or irregular in its outline (fig. 41, *c*). When compressed from above downwards, a condition in which they often occur, a fresh set of appearances is produced (fig. 41, *e, f, g*). In these cases they appear as rounded or oval patches, often very definite in their outline, and exhibiting somewhere within their margin an elevated point, surrounded by several concentric, elliptical, or circular rings, disposed with more or less regularity. The elevated point may be central, or, more commonly, sub-marginal, and it marks the position of the mucro, which thus appears to have been more solid than the remainder of the body. The ridges surrounding the mucro are too irregular to be due to anything beyond mere vertical pressure. In one instance, however (fig. 41, *h*), the entire body is furnished with very distinct and fine concentric striæ, which radiate from the mucro.

In determining the nature of these bodies, we have two points to consider: Firstly, we have to see if there are any structures in living forms which these may be supposed to resemble; and secondly, we may consider if any connection can be shown to exist between these bodies and the accompanying Graptolites.

In considering the resemblances of these curious bodies, I may also include the chitinous capsules which have been shown by Professor Hall and Mr Hopkinson to be in direct connection with the stipes of certain diprionidian Graptolites. In the first place, as regards the above described detached bodies, the analogy presented with the horny ovarian capsules of the Sertularian Zoophytes is extremely obvious, and it is the one which I originally pointed out. They resemble the capsules of the Sertularians in their general shape, and in being horny sacs, which are primitively closed, but which appear ultimately to dehisce and discharge their contents. To show this general likeness, I subjoin a figure of one of the ovarian capsules of the living *Diphasia* (*Sertularia*) *operculata*, Linn. (fig. 42).

So far the resemblance is striking, but the supposed ovarian capsules of the Graptolites differ from the capsules of the Sertularians in some important points, to which I must confess I did not at first attach sufficient weight. The ovarian capsules, namely, of the Sertularians, are never detached from the parent colony, and they develop the reproductive zooids in their interior without ever becoming free. On the other hand, the supposed capsules of the Graptolites are undoubtedly free, at any rate in the later stages of their growth. Again, the capsules of the Sertularians are not only definite in shape, but also in size for each species, and though larger than the ordinary "hydrothecæ," their size is nevertheless

comparatively small. On the contrary, the gradations in size in the supposed capsules of the Graptolites are so numerous, and the disproportion between the extreme terms of the series is so great, that we are forced to believe that each species cannot have had capsules of a uniform size; and it becomes difficult or impossible to resist the conclusion that these

Fig. 42.



Ovarian capsule of *Diphasia* (*Sertularia*) *operculata*, Linn. (After Hincks.) Greatly enlarged.

bodies possessed in their free condition the power of independent growth. Their size, also, as compared with the capsules of the living Sertularians, might fairly be called gigantic. The above-mentioned differences are certainly sufficient to show that the singular horny sacs above described can only be compared in a general way with the "ovarian capsules" of the Sertularian Zoophytes; but I do not think that the differences—great as they are—are wider than those which separate the Graptolites from the colonies of the Sertularians.

When, however, we come to consider the fixed chitinous sacs described by Professor Hall and Mr Hopkinson as occurring in connection with the fronds of *Diplograpsus Whitfieldii* and *D. pristis* (fig. 39), we find a much closer analogy with the ovarian capsules of the *Sertularida*. In both cases we have colonies composed of a number of zoöids contained in little horny cups, producing a number of larger sacs, which remain permanently attached to the parent colony. The capsules of the *Diplograpsi* can be shown to dehisce at their free extremities; and it is evident that dehiscence is followed by their ultimate disappearance. As the soft parts of the Graptolites have disappeared, it is almost out of the question that we should ever obtain more convincing evidence than this as to the substantial identity of the above-named sacs in the *Diplograpsi* with the ovarian capsules of the Sertularians. If I were not fearful, however, of straining analogies too far, one other point of resemblance might be pointed out. Both Hall and Hopkinson, namely, describe the capsules of the *Diplograpsi* as being traversed by chitinous fibres. These, it seems to me, may perhaps be compared with the radiating chitinous tubes which enclose the marsupial chamber in the female capsules of *Diphasia* (*Sertularia*) *rosacea*, Linn., and other allied species.

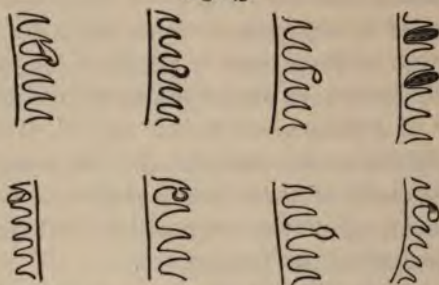
We have now to consider, in the second place, whether any connection can be shown to subsist between the above-mentioned detached bell-shaped sacs and the Graptolites, and the evidence on this head is chiefly indirect. That these sacs are detached portions of Graptolites is rendered probable by the

following considerations:—1. The texture of these sacs is exactly similar to that of the Graptolites themselves, and the marginal fibre by which they are bounded has precisely the structure of the "solid axis," and presents precisely the same appearances. 2. These sacs have only been discovered as yet in conjunction with the remains of Graptolites, and have never been found in any beds in which the latter are wanting. 3. The structure of these sacs is precisely similar to that of the sacs which have been described as occurring attached to the polypary of *Diplograpsus pristis* and *D. Whitfieldii*, and they dehisce in the same manner. 4. The general form and mode of dehiscence of these sacs is such as we might fairly have anticipated, upon the supposition that they are the "ovarian capsules" of the Graptolites.

These general considerations appear to me of themselves sufficient to establish a connection between the Graptolites and these detached sacs, and to render it almost certain that the latter stand to the former in the relation of "ovarian capsules." Formerly, however, I described a number of specimens of one of the simple monoprionidian Graptolites (viz., *G. Sedgwickii*, var. *triangulatus*, Harkness), in which I believed that the stipe exhibited these capsules attached, in a young, and consequently diminutive, condition. These sacs appeared in the form of vesicles apparently attached to various parts of the stipe, but appearing most commonly to be attached to the cellules. I used the term "appeared" advisedly, because I do not wish to express myself dogmatically, and the question is one in which it would be easy to fall into error as to the phenomena observed. Mr Carruthers, of the British Museum, who has made the Graptolites a special study, in commenting upon my observations, expressed his decided opinion that the phenomena described by me were due to the accidental juxtaposition of the Graptolites with these minute sacs. A careful re-examination of my specimens has still left me of the opinion that the phenomena observed are not thus to be explained as merely accidental. In the face, however, of this adverse verdict, and in the absence of any fresh evidence, I shall not insist upon the correctness of my views, the more

especially as I hold this point to be unnecessary as regards establishing the reproductive nature of the capsules. I shall, therefore, content myself simply with giving an illustration of some of the specimens in question (fig. 43), leaving the ques-

Fig. 43.



Examples of *Graptolites Sedgwickii*, var. *triangulatus*, Harkn., showing minute sacs (ovarian capsules?) attached to the stipes (?). (Original.)

tion of the nature of these specimens open to the determinations to be arrived at by future observers and more extended investigations.

Upon a review, then, of the whole evidence, I think we may conclude that the detached bell-shaped corneous sacs which I formerly described as "grapto-gonophores" are truly the cases in which were contained the reproductive zooids of certain of the Graptolites. I think we may safely conclude that this is their nature simply upon the considerations above recounted, irrespective of any demonstration of their being actually connected with the fronds of the Graptolites. I will only add that a good deal of misconception seems to have arisen upon this question in consequence of my having termed these bodies "grapto-gonophores," and having compared them with the "gonophores" of the Sertularian Zoophytes. In making this comparison I employed the term "gonophore" in the sense in which it was originally used by Dr Allman, the inventor of the term, and one of the highest authorities on the entire group of the Hydroid Zoophytes. I employed the name "gonophore," namely, to signify the reproductive bud of the Sertularians, *plus its external chitinous investment*. At

the present day, however, this loose use of the term "gonophore" has been abandoned by most authorities, and a more precise terminology has wisely been adopted. The reproductive zoöid is now spoken of as the "gonozoöid," the protective envelope or investment (when present) is called the "ectotheca" or "gonotheca," and the entire reproductive bud, whatever its nature may be, is spoken of as the "gonophore." This is the terminology adopted by Mr Thomas Hincks in his admirable work on the 'British Hydroid Zoophytes' (Introduction, p. 3, note); but more recently Professor Allman has re-defined the term "gonophore" in a sense different both to his original definition and to the definition given by Mr Hincks (Trans. Royal Soc. Edin., xxvi. 97). Dr Allman now defines the term "gonophore" to be "the ultimate generative zoöid—that which *immediately* produces the generative elements." On this definition the "gonophore" becomes equivalent to the "gonozoöid" of Mr Hincks. Upon the whole, the terminology employed by Mr Hincks is the one which is to be preferred by the palæontologist, as clearly distinguishing by definite names the elements of the generative bud, separating those which are perishable from those which could never be preserved in a fossil condition. On this definition, therefore, the sacs described as attached to the frond of certain of the *Diplograpsi* are to be spoken of as "*gonothecæ*," and the same term should be applied to my "grapto-gonophores" if my views as to the nature of these are to be accepted.

II. DEVELOPMENT.—The first observer who appears to have made any accurate observations upon the development of the Graptolites is Professor James Hall, who described and figured several young forms or "germs" (Grapt. Quebec Group, pp. 33, 34, pl. B. figs. 12-19). Mr Carruthers, however, noticed the occurrence of these young forms at an earlier period—in 1859—and was, I believe, the first to draw attention to their existence (Annals and Magazine of Natural History, iii. No. 13, 1859). The young forms of Graptolites occur in great profusion in almost all strata which contain the adult forms, and though extremely various in their form, they usually

exhibit a general similarity in essential structure. They are almost all very minute, though some few attain a length of as much as $\frac{1}{4}$ of an inch; and I have figured below a number of the more striking forms (fig. 44). The most abundant of these

Fig. 44.



Various young forms of Graptolites, all except *a* considerably enlarged. *a*, A peculiarly large form, natural size; *b*, the same enlarged. (Original.)

young forms consist simply of a minute triangular "radicle," which at first does not conspicuously exhibit a solid axis, seeming to consist of nothing more than the commencement of the cœnosarc with its outer investment. At a later stage, a solid axis becomes visible, either at one side of this minute radicle, or running up its centre. Other forms, presumably of more mature growth, exhibit the primordial cellules, which are developed from the broader end of the radicle, and which appear as lobes upon one or both sides of the radicle, according as the form is monoprionidian or diprionidian (fig. 44, *a*). Other forms, of still later growth, exhibit two or three cellules on each side, when it is sometimes possible to determine to what species they belong. The relationships of these minute "germs," however, with given species are necessarily almost wholly unknown; and it is therefore useless to dwell upon the peculiarities of individual forms, or to do more than indicate the above general details of structure. There remain only two points which are deserving of notice:—

In the first place, we have at present absolutely no means of determining, in the case of some of these germs, which

extremity of the organism is distal and which is proximal. In some of the more advanced forms this point may be readily determined, but in some of the more important examples no decision can be certainly arrived at, and this vitiates the conclusions which might otherwise be drawn. Thus, in *a*, fig. 44, I have figured a large and common young Graptolite in what I am disposed to regard as its natural position; and it is seen to consist of a long triangular radicle, two primitive cellules, and a short distal extension of the solid axis. It is wholly impossible, however, to be sure that the specimen is not *inverted*, and figured upside down. It is perfectly possible that what I regard as the radicle is truly the distal extension of the solid axis, and *vice versâ*. Till, therefore, we can decide with certainty which end of the organism is proximal, it is almost futile to speculate on the mode of growth in these young forms.

In the second place, it should be borne in mind that these so-called "germs" are, in all probability, by no means to be looked upon as the *youngest* forms of the Graptolites. If, on the contrary, the Graptolites are truly referable to the *Hydrozoa*, we have every reason to suppose that their youngest forms were ciliated, and were destitute of any hard investment, so that they could never be preserved to us in a fossil condition. It is very unlikely, therefore, that the young Graptolites were retained within the "ovarian capsules" of their parents, until they reached the stage of development at which a chitinous covering was produced. In accordance with this consideration, we need not expect to find these "germs" actually contained in the interior of the "gonothecæ;" and the examples of young forms in close proximity to the ovarian capsules, figured by Hall and Hopkinson, are to be regarded as cases of merely accidental juxtaposition—as, from the great profusion of the former, they might easily be.

As to the successive development of the different elements of the stipe, we have seen that the common canal would appear to precede the solid axis, and the latter certainly precedes the development of the cellules. The growth of

the solid axis, indeed, appears to a certain extent to be independent of the rest of the organism. As to the development of the *cellules*, I cannot do better than quote the observations of Professor Hall upon this subject. This eminent palæontologist remarks:—

“In regard to the development of the *cellules* in the different parts of the Graptolite, we observe, as a uniform feature, their lesser development towards the base of the stipe. In all the monopropidial forms this character is particularly observable; and in a few species the earlier *cellules* are raised in a scarcely perceptible elevation above the general surface of the common envelope. Indeed, in a few instances it is impossible to ascertain satisfactorily whether these earlier prominences are expanded into open *cellules*. As the stipe is extended, they become gradually more and more prominent, until towards the middle, or oftener perhaps towards the distal extremity, their greatest degree of development is reached. In some species this takes place near the base, and in the more elongated stipes there is no sensible increase throughout a great part of their length, and the two margins of the stipe are essentially parallel. Towards the distal extremity there is a gradual, or often more abrupt, diminution in the size of the *cellules*, and a few of the last ones are much smaller, until the terminal *cellule* is sometimes seen in a partially-developed condition between the common body and the partition of the preceding *cellule*.”

The general state of things, therefore, is to find the fully-developed *cellules* occupying the central portion of the frond, whilst the *cellules* at both extremities of the frond are only

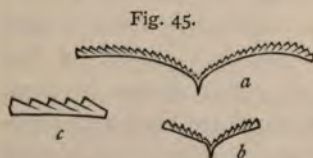


Fig. 45.
Didymograpsus (Graptolithus) nitidus, Hall. (After Hall.)

partially developed (fig. 45). To this it should be added that the *cellules* of the proximal portion of the frond are not only smaller than those which follow them, but are sometimes wholly unlike them in form, as is well seen in *Graptolites sagittarius*, His., and *G. argenteus*,

Nich. That the *cellules* of the distal end of the polypary should be less developed than those of the central portion seems to require no explanation, since this part of the frond would naturally be regarded as the last-produced, growing

portion. It seems, however, very difficult to explain the generally non-developed condition of the cellules towards the proximal portion of the frond ; and I was at one time led to think that perhaps new cellules might be intercalated between the radicle and the cellule immediately above. The rigid corneous investment of the coenosarc would seem, as pointed out by Mr Carruthers, to render this an impossibility, and I am unable to render any explanation of this general fact. I may mention, however, that there are forms, such as *D. cometa*, Gein., and some varieties of *D. folium*, His., in which the proximal pair of cellules are the longest and best developed ; so that the frond attains its maximum breadth immediately above its base.

CHAPTER VII.

ZOOLOGICAL POSITION OF THE GRAPTOLITES.

I.—Mode of Existence.

AS regards the mode of existence of the Graptolites, I have little to add to the remarks which I have previously made in speaking of the nature and functions of the base. I have already endeavoured to show that all the evidence is opposed to the belief that the "radicle" is, or could be, an organ of attachment; and we have sometimes conclusive proof that the organism could not possibly have been attached at this point. This is the view held by Hall, and there does not appear to be a particle of evidence in support of the opposite opinion. We may, therefore, safely conclude that the "radiculate" Graptolites, comprising all the undoubted and typical members of the group, were, in their mature condition, "free-floating bodies in the Silurian seas." This belief would separate the Graptolites very widely, as regards their habits, from both the Sertularian Zoophytes and the *Polyzoa*; for none of the former, and only one aberrant form of the latter, are free. This question, however, would hardly affect the weight to be attached to the essential details of their structure, by which, and not by their mode of life, the zoological position of the Graptolites must ultimately be settled.

Admitting, then, that all the typical Graptolites were free organisms, there remain some genera ordinarily included in this group of which this statement could not safely be made. The genera I allude to are *Dictyonema*, *Dendrograpsus*, *Callo-*

grapsus, and *Ptilograpsus* (leaving out of sight the doubtful forms, *Thamnograpsus*, *Buthograpsus*, and *Inocaulis*), all of which are referred by Hall to the *Graptolitidæ*; and in all, as previously pointed out, there is considerable reason to think that the frond was fixed in its adult condition. Be this as it may, there can be no question as to the great divergence of these forms, in other respects, from the typical Graptolites; and it seems certain that a more extensive knowledge of their characters will inevitably result in the removal of these genera to some other group, allied to the true Graptolites, but at least ordinally distinct.

II.—Systematic Position and Affinities.

The earlier views as to the nature of the Graptolites have a merely historical value, and the same may be said of some of the later opinions. Originally regarded as plants, they have been, at different times and by different authorities, referred to the *Cephalopoda*, the *Actinozoa*, the *Hydrozoa*, the *Polyzoa*, the *Echinodermata*, and the *Foraminifera*. There are, however, but three of these groups to which the Graptolites show any real resemblance—viz., the *Actinozoa*, the *Hydrozoa*, and the *Polyzoa*; and almost all modern observers refer them to one or other of the two last-named groups. It will be sufficient, therefore, to notice the affinities presented by the Graptolites to these three groups respectively:—

1. ACTINOZOA.—Dr Beck of Copenhagen first suggested that the Graptolites were most nearly related to the *Virgularia* of recent seas, and that they should be placed in the family of the *Pennatulidæ*; and this opinion was first promulgated in Britain by Sir Roderick Murchison (*Sil. System*, p. 695; 1839). The only actual point of resemblance which can be adduced as existing between the Sea-rods and the Graptolites is the existence in each of an axis upon which the colony is supported. There is, however, nothing but the slightest analogy between the "solid axis" of the Graptolites and the axial rod or "sclerobasis" of *Virgularia*. The former is a chitinous fibre, almost certainly tubular, and unquestionably *outside* the *cœnosarc*, in all forms in which its posi-

tion can be accurately determined. The latter is a calcareous rod, which is surrounded by the cœnosarc, as a tree is surrounded by its bark ; and even if we regard the cœnosarc as inverted, its position is essentially different to that of the solid axis of the Graptolite. This loose analogy, however, constitutes the entire basis of comparison between the Graptolites and *Virgularia*, and in all the fundamental points of their structure they are wholly dissimilar. Thus, in *Virgularia* the cœnosarc secretes no external envelope, and the polypes are naked, and are not protected by chitinous cups. We may, therefore, unhesitatingly reject the view that the Graptolites are referable to the *Pennatulidæ*, whilst fully recognising that Dr Beck's suggestion was one which exhibited considerable acumen, and which was a great advance upon all the theories previously entertained upon this subject.

2. POLYZOA.—The leading modern authority who favoured the view that the Graptolites were *Polyzoa* was the late Mr Salter, and he retained this view up to the time of his death. When we come, however, to examine the grounds for this belief, it does not appear that the affinities of the Graptolites with the *Polyzoa* are very numerous, though some of them are undoubtedly very remarkable. In comparing the Graptolites with the *Hydrozoa* and *Polyzoa* respectively, we are, of course, restricted wholly to the hard parts or polyparies ; and we are in no way assisted by the great differences which exist between the zoöids of the *Hydrozoa* and the *Polyzoa*, since we have no means of determining the structure of the soft parts of the Graptolites.

The chief points which are of importance to us in our present inquiry as regards the structure of the *Polyzoa* are the following :—

In the first place, as a *general rule*, the separate cells which compose the "polyzoarium" do not communicate with one another otherwise than by continuity of their external integument. If this rule were universal, it would afford a distinction by which the Graptolites could be at once removed from the *Polyzoa* ; for the former certainly consist of a number of zoöids springing from a cœnosarc. Unfortunately, however,

in many *Polyzoa* there is a certain amount of communication between the different zoöids, as shown by the existence of a "colonial" nervous system; and in one sub-order (viz., the *Ctenostomata* of Busk) the polyzoarium consists of a series of cells arising from a common tube. We cannot, therefore, employ this point as an absolute means of separation between the Graptolites and the *Polyzoa*. It remains certain, however, that the *general* structure of the "polyzoarium" is sharply distinguished from the polypary of the Graptolites by the above-mentioned character.

Secondly, the "polyzoarium" is commonly more or less highly charged with carbonate of lime, and this is especially the case with the fossil forms. The polypary of the Graptolites, on the other hand, is invariably corneous (or chitinous). Still, a good many of the *Polyzoa* have a merely corneous polypidom, so that this point also cannot be insisted on.

In the third place, all the typical Graptolites, including probably all the forms truly referable to the family, were undoubtedly *free* organisms. All the *Polyzoa*, on the contrary, with the single exception of the wholly anomalous fresh-water genus *Cristatella*, are *fixed* and rooted in their adult condition. This, I believe, is a true and most important distinction between the *Polyzoa* and the *Graptolitidæ*; and it is one which is no way affected by the possibility that *Dictyonema* and its allies were fixed—partly because this is only inferred and is not certainly known, and partly because there are other good reasons for not regarding these genera as belonging to the Graptolites at all.

Fourthly, the zoöids of the colony of a *Polyzoön* are sexually perfect, and each is provided with *internal* organs of reproduction. In the case of some of the *Diplograpsi*, however, we have evidence that the reproductive organs were developed in outward processes of the body-wall, as is essentially characteristic of the *Hydrozoa*; and we may infer that this was probably the case with all the Graptolites. This, therefore, if conclusively established, would constitute a most satisfactory ground for removing the Graptolites from the *Polyzoa*, and placing them amongst the *Hydrozoa*. It should not be for-

gotten, however, that all observers would not probably admit the reproductive nature of the external sacs found attached to certain of the *Diplograpsi*; and it is undoubtedly a matter requiring explanation why so few individuals should have been discovered with these appendages amongst so many thousands of specimens, if these bodies are of the nature of the "ovarian capsules" of the Sertularians. It should also be borne in mind that we have in the so-called "statoblasts" of the *Polyzoa* an instance of non-sexual reproduction, in which there are produced, as internal buds, horny lenticular bodies, consisting of "two concavo-convex discs united by their margins, where they are further strengthened by a ring which runs round the entire margin, and is of different structure to the discs" (Allman). These "statoblasts" are liberated from the zoöid which produces them, when they float about, ultimately dehiscing by the separation of the two component discs, and giving exit to a young *Polyzoön*.

Lastly, in the singular *Rhabdopleura Normani* described by Professor Allman, we are presented with a *Polyzoön* in which, alone of all living forms, there is a structure which can be compared with the "solid axis" of the Graptolites. The "polyzoarium" in this extraordinary form is "a branched, adherent, membranous tube, in whose walls, along their adherent side, a rigid chitinous rod extends, and whose branches terminate each in a free open tube, through which the polypides emerge." The chitinous rod of *Rhabdopleura* contains an axial channel, and follows all the ramifications of the polyzoarium, but it stops short at the bases of the tubes in which the polypides are contained, and the polypides are connected to it by a flexible cord or "funiculus." In many respects this chitinous rod closely resembles the "solid axis" of the Graptolites, and no parallel so near can as yet be pointed out in any other living form. The solid axis, however, of the Graptolites presents some phenomena of which no traces are seen in the chitinous rod of *Rhabdopleura*, and these phenomena are of much more than merely superficial importance. Foremost amongst these is the very common prolongation of one or both ends of the solid axis beyond the limits of the

polypary. It should also be noted that the general structure of *Rhabdopleura* is in no way comparable with that of a Graptolite, and the chitinous rod of the former is the only point of resemblance. Upon the whole, therefore, the affinities between *Rhabdopleura* and the Graptolites are not sufficiently strong to outweigh the general differences between the latter and the *Polyzoa*, and do not touch the great gulf necessarily caused by the fact that the Graptolites were free organisms, whilst the *Polyzoa*, with one wholly unimportant exception, are fixed.

It only remains to be added that *Dictyonema* and its allies, *Dendrograpsus* and *Callograpsus*, approach the *Polyzoa* much more nearly than do any of the typical Graptolites. In all these forms the polypary is branched and plant-like, and may possibly have been fixed. *Dictyonema*, especially, shows a very close external resemblance to the *Fenestellæ*. The presence of "cellules," however, may generally be made out, and this would certainly remove the *Dictyonemæ* from all forms such as *Fenestella* and *Retepora*. I have already expressed my opinion, however, that *Dictyonema* and its allies cannot properly be retained in the family of the *Graptolitidæ*, whilst I think their affinities are much closer with the Sertularian Zoophytes than with the *Polyzoa*.

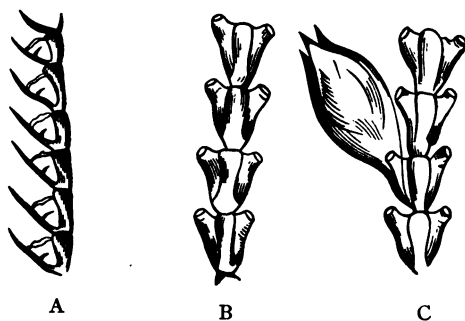
3. HYDROZOA.—The first to suggest the affinities of the Graptolites with the modern group of the *Hydrozoa* was Professor Nilsson; but it was General Portlock who first definitely suggested that they were allied to the Sertularian Zoophytes, and were related to the recent *Sertularia* and *Plumularia*. (Geol. Rep. on Londonderry, &c., 1843.) This view was also adopted by Professor M'Coy; and almost all modern observers are at one in placing the Graptolites somewhere amongst the *Hydrozoa*, though there may be differences of opinion as to their exact place in this class.

When we remember the structure of a Graptolite, it is at once obvious that the only living *Hydrozoa* to which they can be directly compared are those "Hydroid Zoophytes" in which there is a horny skeleton or "polypary." Not only so, but we can only compare the Graptolites with those Hydroids

in which the individual zoöids are protected by chitinous cups or "hydrothecæ." This eliminates the *Corynida*, and limits our choice to the *Sertularida* and *Campanularida* (the *Thecaphora* of Hincks). In the Campanularians the "hydrothecæ" are pedunculate and terminal in position, occupying the extremities of the branches; and as this is not known to occur in any Graptolite, we may confine our attention to the Sertularians, in which the "hydrothecæ" are sessile and placed laterally on the branches.

The general points of resemblance between the Sertularian Zoophytes and the Graptolites are very obvious, and may be stated as follows:—Both consist of a number of zoöids, each contained in a chitinous cup or "hydrotheca," united by a common body or cœnosarc which secretes a firm chitinous outer investment. In both there are forms with "hydrothecæ" upon one side only of the branches or upon both, and, as shown in the subjoined illustration (fig. 46), the general shape and arrange-

Fig. 46.



A, A fragment of *Plumularia pennatula*, magnified, showing a single row of hydrothecæ. B, A fragment of *Sertularia fallax*, magnified, showing a double row of hydrothecæ. C, Fragment of *Sertularia fallax*, magnified, showing an ovarian capsule. (After Johnston.)

ment of the "hydrothecæ" of the Sertularians is by no means unlike what is observed in some of the Graptolites. Further, the "hydrothecæ" of the Sertularians are not shut off from the cœnosarc by a perforated diaphragm or septum, just as the

"cellules" of the Graptolites are similarly unrestricted in their communication with the "common canal." Lastly, the reproductive organs of the Sertularians are developed in special zoöids, which are contained in chitinous urn-shaped sacs or "gonothecæ," which are only developed at certain seasons, and which are much larger than the ordinary "hydrothecæ" (fig. 46). These "gonothecæ" may well be compared with the chitinous sacs found attached to the sides of certain specimens of *Diplograpsus pristis* and *D. Whitfieldii*; and they present a singular resemblance in form to the corneous bell-shaped bodies which are found amongst the Graptolites in a detached form, and which I originally described as "grapto-gonophores."

The above points of resemblance are the most important ones which can be mentioned as existing between the Sertularian Zoophytes and the Graptolites; but there are other almost equally numerous and striking points of dissimilarity. Foremost amongst these is the fact that the typical Graptolites were free organisms, whilst the Sertularians are uniformly fixed. The solid axis of the Graptolites, again, is wholly unrepresented by any even approximately similar structure amongst the Sertularians. Further, the "hydrothecæ" of the Sertularians are not in contact, whilst the "cellules" of the Graptolites almost always overlap, and are separated by definite internodes in the genus *Rastrites* only. Lastly, there is reason to believe that the "gonothecæ" of the Graptolites, if they are truly to be regarded as such, were not uniformly attached to the parent organism, but that in some species they were detached, in their later stages at any rate, if not from the first. As already remarked, also, it still remains to be explained how it is that so few individuals (indeed, a single one only) of such a common species as *Diplograpsus pristis* should have been as yet discovered with reproductive capsules attached to the frond, if the ordinary mode of reproduction was by the production of bodies similar to the "ovarian capsules" of the Sertularian Zoophytes.

Upon the whole, then, we seem forced to come to the con-

clusion that whilst the typical Graptolites find their *nearest* living allies in the Sertularians, and are truly referable to the *Hydrozoa*, they cannot properly be regarded as fossil representatives of the *Sertularida*; nor, indeed, can they be placed in any living group of the *Hydrozoa*. In their free habit, they may be compared with the recent Oceanic *Hydrozoa*, and the central disc of some Graptolites may perhaps be safely paralleled with the "float" of the *Physophoridae*. The *Oceanic Hydrozoa*, however, are universally destitute of a polypary, and their general structure differs greatly from that of the Graptolites. We are compelled, therefore, to regard the *Graptolitidae* as constituting a special group of the *Hydrozoa* not represented by any living forms, and their peculiarities are sufficiently numerous and distinctive to entitle them, in my opinion, to the rank of a distinct sub-class. This determination would seem to be warranted by the conjunction, in the typical Graptolites, of a corneous polypary with a free habit of life, by the presence of a "solid axis," and by the peculiarities which seem to distinguish their mode of reproduction.

When, however, we come to consider the place of the genera *Dictyonema*, *Dendrograpsus*, *Callograpsus*, and *Ptilograpsus*, at present provisionally grouped with the typical Graptolites, we find the similarities with the Sertularians remaining nearly the same, whilst the differences are considerably reduced in number. The above-mentioned genera all possess a horny polypary, consisting of "hydrothecæ" united by the chitinous investment of the coenosarc. The "solid axis" of the typical Graptolites is now almost certainly absent. There is great reason to believe that the polypary was fixed, and its general form is branched and plant-like. Indeed, some forms, such as *Ptilograpsus*, have the closest possible external resemblance to some of the living Sertularians, such as some of the *Plumulariæ*. In the essential points of their structure, therefore, these genera agree very closely with the ordinary Sertularian Zoophytes; and if we were but convinced that the polypary was fixed, and that the reproductive process took place by

the formation of attached "ovarian capsules," we could have no hesitation in regarding these forms as fossil representatives of the *Sertularida*. In the absence, however, of these two important links in the chain of evidence, it is safest not to dogmatise on the systematic position of *Dictyonema* and its allies ; at the same time that their general structure certainly seems to warrant their removal from the *Graptolitidæ* proper.

CHAPTER VIII.

GEOLOGICAL DISTRIBUTION OF THE GRAPTOLITIDÆ.

THE subject of the geological distribution of the Graptolites is a wide one, and I shall here merely treat of this subject in a general way, reserving details till I come to speak at length of the genera and species of the *Graptolitidæ*.

That the Graptolites were exclusively confined to the Silurian Rocks, and were characteristic of the Silurian life-period, was a generalisation put forth by Sir Roderick Murchison, and the latest researches seem likely to establish this opinion. So far, at any rate, as is at present known, no member of the typical Graptolites has been detected above the summit of the Silurian Series. The only supposed Graptolites which have survived this period are referable to the genus *Dictyonema*, Hall. I have, however, already given reasons for the belief that this genus is not truly to be included in the *Graptolitidæ*. If, therefore, we leave this doubtful genus out of consideration, the Graptolites may be said to be exclusively Silurian fossils. Not only is this the case, but the Graptolites, as regards their individual abundance and the number of generic and specific types, are far more characteristic of the Lower than the Upper Silurian Rocks. And, finally, the inferior portion of the Lower Silurian Series can claim a decided predominance in the number of genera, as compared with the higher deposits of the same series. It is to be remembered, however, that the lowest sediments in which Graptolites occur—viz., the Tremadoc Slates and Skiddaw Slates of Britain, and the Potsdam Sandstone and

Quebec Group of North America—would by many geologists (including myself) be regarded as being of Upper Cambrian age. These deposits, nevertheless, are so closely connected with the base of the Lower Llandeilo Rocks, that our present purpose will be served by including them in the Lower Silurian Series.

In considering the distribution in time of the Graptolites of Britain, we may distinguish three periods, which are likewise recognisable in North America. These three periods are :—1. The Skiddaw and Quebec Period ; 2. The Llandeilo and Caradoc Period ; and, 3. The Upper Silurian Period.

1. THE SKIDDAW AND QUEBEC PERIOD.—The rocks of this period are variously regarded as forming the summit of the Upper Cambrians or the base of the Lower Llandeilos, and for our present purpose it does not matter which view is adopted. The Skiddaw Slates of Britain occupy an inconsiderable area of the Lake-district of the North of England ; but they attain a thickness not less than from 5000 to 7000 feet. The strata of the Quebec Group occupy a very extensive area in both Canada and the United States, though they are not known to yield Graptolites except in the former country. Both the Skiddaw Slates of Britain and the Quebec Rocks of Canada are characterised by an extensive and peculiar assemblage of Graptolites, many genera and not a few species being common to the two formations ; whilst the greater number of the genera are exclusively confined to this horizon. The following table exhibits the generic types which are known to occur in the rocks of the Skiddaw and Quebec period, those which reappear in later deposits being distinguished by an asterisk :—

TABLE

TABLE OF THE GENERA OF GRAPTOLITES IN THE SKIDDAW AND QUEBEC SERIES.

* Climacograpsus, . . .	Britain and Canada.
* Diplograpsus, . . .	— — —
* Didymograpsus, . . .	— — —
* Pleurograpsus, . . .	Britain (?)
Dichograpsus, . . .	Britain and Canada.
Tetragrapsus, . . .	— — —
Loganograpsus, . . .	— — —
Phyllograpsus, . . .	— — —
Trigonograpsus, . . .	Britain and Canada (?)
* Dendrograpsus, . . .	Britain (?) Canada.
Callograpsus, . . .	Canada.
* Retiograpsus, . . .	Canada.
* Dictyonema, . . .	Canada.
* Thamnograpsus, . . .	Canada.
* Ptilograpsus, . . .	Canada.

From the above table it will be evident that the Skiddaw period in Britain is characterised by the exclusive possession of the genera *Dichograpsus*, *Tetragrapsus*, *Loganograpsus*, *Phyllograpsus*, and *Trigonograpsus*. The first three of these are complex branched forms, and are peculiarly characteristic of this period, as is the compound type, *Phyllograpsus*. It may be added that of the genera which are not peculiar to this horizon, *Didymograpsus* is particularly well represented, at least eight species being known, of which five are not, known to survive into later deposits. Lastly, out of a total of about thirty-two species which have been detected in the Skiddaw Slates of Britain, only four species pass upwards into the Upper Llandeilo Rocks, twenty-six being peculiar to the Skiddaw Slates, and two species being known to occur in the Lower Llandeilo Rocks of other regions.

2. UPPER LLANDEILO AND CARADOC PERIOD.—As far as the Graptolites are concerned, the rocks of the Upper Llandeilo and Caradoc or Bala formations may be grouped together as forming a single period, though peculiar forms are found in each. The leading Graptolitiferous rocks of the first of these formations are the Upper Llandeilo Shales of the south of Scotland, and the Llandeilo Flags of Wales.

The more important deposits of the second division of this period are the Coniston Mudstones of the North of England, the Gala Group of Scotland, certain rocks of the same age in Ireland, and the Hudson River and Utica Slates of North America. The following table exhibits the genera which are known to have existed in this period, those which survived into the Upper Silurian Rocks being marked with an asterisk:—

TABLE OF THE GENERA OF GRAPTOLITES IN THE UPPER LLANDEILO AND CARADOC ROCKS OF BRITAIN.

- Diplograpsus.
- Climacograpsus.
- Didymograpsus (very rare in Caradoc of Britain).
- Dicranograpsus (not known in Caradoc in Britain).
- Cænograpsus (not known in Caradoc of Britain).
- Pleurograpsus (not known in Caradoc in Britain).
- * Cyrtograpsus? (not in Llandeilo).
- Rastrites.
- * Retiolites.
- * Graptolites.

Of the above ten genera which collectively characterise the Llandeilo - Caradoc period in Britain, *Climacograpsus*, *Diplograpsus*, and *Didymograpsus* commenced in the earlier period of the Skiddaw Slates, and *Climacograpsus* alone survives into the Lower Llandovery. *Didymograpsus* is well represented in the Upper Llandeilo or lower division of this period, but had almost died out before the Caradoc period in Britain, not being known in either the Coniston Mudstones of the north of England or the Gala Group of Scotland. It occurs, however, in Caradoc Rocks in Ireland, and is well represented in the Hudson River Group in America. The genera *Dicranograpsus*, *Cænograpsus* (= *Helicograpsus*), and *Pleurograpsus* appear for the first time, but do not survive the Upper Llandeilo, and are not known in the Caradoc Rocks in Britain, though the two former are found in beds of Caradoc age in North America. *Cyrtograpsus* (?) and *Rastrites* have here their first appearance, and the latter dies out with the close of the Caradoc period in Britain. Lastly, *Retiolites* and *Graptolites*, with some doubtful exceptions of an older

date, appear here for the first time, are represented throughout the whole of this period, and survive into the succeeding period of the Upper Silurian Rocks.

3. UPPER SILURIAN PERIOD. — In the Upper Silurian Rocks of Britain only four genera of Graptolites are as yet known to be represented—viz. *Graptolites*, *Retiolites*, *Cyrtograpsus*, and *Ptilograpsus*. The last being very doubtfully referable to the *Graptolitidæ*, there remain only the three genera above mentioned as the sole representatives of the extensive Graptolitic fauna of the Lower Silurian area of Britain. All these genera, also, disappear at the close of the Upper Silurian period.

It is to be remembered, however, that several of the genera and many of the species characteristic of the Caradoc deposits of Britain pass upwards in Bohemia into strata believed by M. Barrande to constitute the base of the Upper Silurian Series. In this area, therefore, the genera *Diplograpsus*, *Climacograpsus*, and *Rastrites* are not peculiar to the Lower Silurian rocks, but survive into strata belonging to the Upper division of the system. But for this as yet solitary exception, it might have been asserted that no diprionidian Graptolite, save the aberrant *Retiolites*, occurred in rocks younger than the Lower Silurian. As it is, we can merely say that *Diplograpsus* and *Climacograpsus* are essentially and principally Lower Silurian genera, and that in Britain and North America they are exclusively so.

The following Table gives approximately the number and range of the British species of Graptolites; but it is not pretended either that all the forms here included are truly referable to this family, or that they are all valid species; whilst a good many have been excluded, either because I think their specific distinctness very questionable, or because they have not yet been described:—

TABLE SHOWING THE GEOLOGICAL DISTRIBUTION OF THE SPECIES OF
GRAPTOLITIDÆ IN BRITAIN.

SPECIES.	Tremadoc Slates.	Skiddaw Slates.	Lower Llandello.	Upper Llandello.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock.	Ludlow.
<i>Dichograpsus annulatus, Nich.,</i>	..	*							
<i>gracilis, Nich.,</i>	..	*							
<i>multiplex, Nich.,</i>	..	*							
<i>octobrachiatus, Hall,</i>	..	*							
<i>reticulatus, Nich.,</i>	..	*							
<i>Loganograpsus Logani, Hall,</i>	..	*							
<i>Tetragrapsus bryonoides, Hall,</i>	..	*							
<i>crucifer, Hall,</i>	..	*							
<i>Headi, Hall,</i>	..	*							
<i>quadribachiatus, Hall,</i>	..	*							
<i>Phyllograpsus angustifolius, Hall,</i>	..	*							
<i>typus, Hall,</i>	..	*							
<i>Anna, Hall,</i>	..	*							
<i>Trigonograpsus lanceolatus, Nich.,</i>	..	*							
<i>Climacograpsus antennarius, Hall,</i>	..	*							
<i>teretiusculus, His.,</i>	..	*	*	*	*	*			
<i>bicornis, Hall,</i>	..	*	*	*					
<i>tuberculatus, Nich.,</i>	..	*	*	*					
<i>innotatus, Nich.,</i>	..	*	*	*					
<i>Diplograpsus acuminatus, Nich.,</i>	..	*	*	*	*				
<i>angustifolius, Hall,</i>	..	*	*	*	*				
<i>armatus, Nich.,</i>	..	*	*	*	*				
<i>bimucronatus, Nich.,</i>	..	*	*	*	*				
<i>cometa, Gein.,</i>	..	*	*	*	*				
<i>confertus, Nich.,</i>	..	*	*	*	*				
<i>folium, His.,</i>	..	*	*	*	*				
<i>Harknessi, Nich.,</i>	..	*	*	*	*				
<i>Hopkinsoni, Nich.,</i>	..	*	*	*	*				
<i>Hughesi, Nich.,</i>	..	*	*	*	*				
<i>insectiformis, Nich.,</i>	..	*	*	*	*				
<i>mucronatus, Hall,</i>	..	?	*	*	*				
<i>nodosus, Harkn.,</i>	..	*	*	*	*				
<i>palmeus, Barr.,</i>	..	*	*	*	*				
<i>pristiniformis, Hall,</i>	..	*	*	*	*				
<i>pristis, His.,</i>	..	*	*	*	*				
<i>putillus, Hall,</i>	..	*	*	*	*				
<i>sinuatus, Nich.,</i>	..	*	*	*	*				
<i>tamariscus, Nich.,</i>	..	*	*	*	*				
<i>vesiculosus, Nich.,</i>	..	*	*	*	*				
<i>Whitfieldii, Hall,</i>	..	*	*	*	*				
<i>Didymograpsus affinis, Nich.,</i>	..	*	*	*	*				
<i>anceps, Nich.,</i>	..	*	*	*	*				
<i>bifidis, Hall,</i>	..	*	*	*	*				

SPECIES.	Tremadoc Slates.	Skiddaw Slates.	Lower Llandello.	Upper Llandello.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock.	Ludlow.
<i>Didymograpsus divaricatus, Hall</i> , ...	...	...	...	*					
<i>fasciculatus, Nich.</i> , ...	...	*	...	*					
<i>flaccidus, Hall</i> , ...	...	...	...	*					
<i>geminus, His.</i> , ...	...	*	*	*					
<i>Murchisoni, Beck.</i> , ...	...	...	...	*					
<i>nitidus, Hall</i> , ...	...	*	...	*					
<i>patulus, Hall</i> , ...	...	*	*						
<i>serratus, Hall</i> , ...	...	*	*						
<i>sextans, Hall</i> , ...	...	?	...	*					
<i>V-fractus, Salt.</i> , ...	...	*	...						
<i>Dicranograpsus Clingani, Carr.</i> , ...	...	...	...	*					
<i>formosus, Hopk.</i> , ...	...	...	...	*					
<i>Nicholsoni, Hopk.</i> , ...	...	...	...	*					
<i>ramosus, Hall</i> , ...	...	...	*	*	?				
<i>Graptolites argenteus, Nich.</i> , ...	...	...	...	*	*				
<i>Bohemius, Barr.</i> , ...	...	...	...	*	*				
<i>Clingani, Carr.</i> , ...	...	...	...	*	*				
<i>colonus, Barr.</i> , ...	...	...	...	*	*	...	...	*	*
<i>discretus, Nich.</i> , ...	...	...	...	*	*				
<i>exiguus, Nich.</i> , ...	...	...	...	*	*				
<i>fimbriatus, Nich.</i> , ...	...	...	...	*	*				
<i>Flemingii, Salt.</i> , ...	...	...	...	*	*				
<i>lobiferus, M^cCoy.</i> , ...	...	...	...	*	*	...	...	*	
<i>Nilsoni, Barr.</i> , ...	...	...	...	*	*				
<i>priodon, Brown.</i> , ...	...	...	...	*	*	*	*	*	*
<i>sagittarius, His.</i> , ...	...	?	...	*	*	*	*	*	
<i>Sedgwickii, Portl.</i> , ...	...	...	...	*	*				
<i>tenuis, Portl.</i> , ...	...	...	...	*	*				
<i>turriculatus, Barr.</i> , ...	...	...	...	*	*				
<i>vomerinus, Nich.</i> , ...	...	...	...	*	*	...	...	*	
<i>Rastrites capillaris, Carr.</i> , ...	...	...	...	*	*				
<i>Linnæi, Barr.</i> , ...	...	...	...	*	*				
<i>maximus, Carr.</i> , ...	...	...	...	*	*				
<i>peregrinus, Barr.</i> , ...	...	...	...	*	*				
<i>Retiolites Geinitzianus, Barr.</i> , ...	...	...	...	*	*	...	...	*	*
<i>perlatus, Nich.</i> , ...	...	...	...	*	*				
<i>venosus, Hall</i> , ...	...	...	...	*	?				
<i>Cœnograpsus (Helicograpsus) gracilis, Hall</i> , ...	...	...	...	*					
<i>Pleurograpsus linearis, Carr.</i> , ...	...	...	...	*					
? <i>vagans, Nich.</i> , ...	...	*	...						
<i>Cyrtograpsus Murchisoni, Carr.</i> , ...	...	...	...	?	...	...	...	*	
<i>Ptilograpsus Anglicus, Nich.</i> , ...	...	...	...	...	...	...	...	*	*
<i>Callograpsus elegans, Hall</i> , ...	...	...	...	*					
<i>Dictyonema socialis, Salt.</i> , ...	*	...	...	*					
<i>gracilis, Hall</i> , ...	...	...	...	*					
<i>Dendrograpsus Hallianus, Prout. (?)</i> , ...	...	*	*						
<i>flexuosus, Hall</i> , ...	...	...	...	*					

CHAPTER IX.

GENERA OF THE GRAPTOLITIDÆ.

IN the following chapter I purpose shortly considering the characters of the various genera into which the family of the *Graptolitidæ* may be divided. In so doing, I shall not confine myself to the typical and undoubted Graptolites, but I shall also consider the forms which may be provisionally retained here in the absence of a more definite knowledge of their true affinities, along with some other forms which are almost certainly not Graptolites, but the exact nature of which is doubtful. I shall, however, omit the consideration of several genera which are now abandoned by palæontologists, and some of which are now known to have been founded upon objects in no way referable to the *Graptolitidæ*. I shall, then, in the first place, give a synopsis of the genera of the true "radiculate" Graptolites.

CLASS HYDROZOA.

Sub-class Graptolitidæ.

Hydrozoa, in which the hydrosoma is compound and free, consisting of numerous polypites united by a cœnosarc, the latter being enclosed in a strong tubular polypary, whilst the former are protected by "hydrothecæ." The polypites not separated from the cœnosarc by any partition, and the polypary generally supported by a chitinous rod or "solid axis."

In framing the above definition, the genera *Dendrograpsus*, *Ptilograpsus*, *Callograpsus*, and *Dictyonema*, which may in the

meanwhile be called the "Dendroid" Graptolites, have been left out of account, as have been the genera *Buthograpsus*, *Thamnograpsus*, *Inocaulis*, and *Corynoides*, the true nature of which is still more uncertain.

As regards the division of the family *Graptolitidæ*, as above defined, into smaller divisions, a primary basis of classification is afforded by the presence of cellules upon one side of the polypary and its branches only, or upon both sides. This distinction was early recognised by M. Barrande, who founded upon this character his two groups of *Monoprion* and *Diprion*, which have been subsequently modified by Mr Hopkinson into *Monoprionidæ* and *Diprionidæ*. This last-mentioned observer has added a third group for the *Phyllograpsi*, in which the polypary has four rows of cellules, under the name of *Tetraprionidæ*. The group of *Monodiprionidæ*, founded by Mr Hopkinson to include the genus *Dicranograpsus*, in which part of the polypary is unicellular and part bicellular, I think unnecessary, as these forms are essentially diprionidian, and may well be included in the second group. Adopting these divisions, the family of the *Graptolitidæ* may be divided as follows :—

SYNOPTICAL TABLE OF THE GENERA OF THE GRAPTOLITIDÆ.

A. SECTION MONOPRIONIDÆ.—Polypary and its branches with a single series of cellules—

1. *Graptolites* or *Graptolithus*, Linn.
2. *Didymograpsus*, M'Coy.
3. *Tetragrapsus*, Salter.
4. *Dichograpsus*, Salter.
5. *Loganograpsus*, Hall.
6. *Pleurograpsus*, Nich.
7. *Cænograpsus*, Hall (= *Helicograpsus*, Nich.)
8. *Cyrtograpsus*, Carr.
9. *Rastrites*, Barr.

B. SECTION DIPRIONIDÆ.—Polypary with a double row of cellules over the whole of its length, or towards its proximal end only—

10. *Diplograpsus*, M'Coy.
11. *Climacograpsus*, Hall.
12. *Dicranograpsus*, Hall.
13. *Retiolites*, Barr.
14. *Trigonograpsus*, Nich.
15. *Retiograpus*, Hall.

C. SECTION TETRAPHRIONIDÆ.—Polypary with four rows of cellules—

16. *Phyllograpsus*, Hall.

D. SECTION DENDROIDEA.—Polypary much branched and plant-like. Hydrosoma fixed by its proximal extremity? No solid axis. (These forms are very doubtfully referable to the *Graptolitidæ*.)

17. *Ptilograpsus*, Hall.
18. *Dendrograpsus*, Hall.
19. *Callograpsus*, Hall.
20. *Dictyonema*, Hall.

E. INCERTÆ SEDIS.—Forms probably not referable to the Graptolites, but occurring in the same beds, and having more or less affinity with them. True nature doubtful, and not the same in all cases—

21. *Thamnograpsus*, Hall.
22. *Buthograpsus*, Hall.
23. *Inocaulis*, Hall.
24. *Corynoides*, Nich.

SECTION A. MONOPRIONIDÆ.

I. GENUS GRAPTOLITES *vel* GRAPTOLITHUS, Linn.—*Polypary simple, linear, commencing with a more or less attenuated, generally curved base, and possessing but a single row of cellules on one side. The cellules usually overlapping to a greater or less extent, and never separated by non-polypiferous portions of the common canal (fig. 47).*

As above defined, the genus *Graptolites* does not at all correspond with the *Graptolithus* of Linnæus. It is, however, quite uncertain what species of Graptolites were included in the Linnæan genus, and the name has been so long and so currently employed in the above-mentioned restricted signification, that it would cause the greatest confusion to introduce any change now. The genus *Graptolites*, then, may be con-

fined to those forms which consist of a single simple stipe, with a single row of cellules on one side. The base or commencement of the stipe may be either straight or curved, but in either case the cellules near the base are only partially developed, and they are not only smaller than the cellules of the adult portion of the polypary, but they are very generally different in shape as well. In complete specimens the base is seen to be marked by a radicle, which is short and blunt in some forms (*G. turriculatus*, Barr.), but is long in others (*G. sagittarius*, His., and *G. argenteus*, Nich.), whilst it is occasionally double (*G. colonus*, Barr.) The solid axis in the young forms is prolonged as a naked rod beyond the distal extremity of the polypary, and this sometimes occurs in adult forms (*G. Clingani*, Carr., fig. 6). There may also be a proximal extension of the solid axis as well, though this is certainly rare.

Fig. 47.



Graptolites priodon, Bronn.
Enlarged. From specimens
in the lower part of the
Coniston Flags of the north
of England. (Original.)

A very large series of forms would be included by the above definition, of which *G. Sedgwickii*, Portl., *G. sagittarius*, His., *G. priodon*, Bronn., and *G. lobiferus*, M'Coy, may be taken as common and typical examples. As defined, however, by Professor Hall, the genus becomes totally different. Hall, in fact, employs the term *Graptolithus* to include *all* the ordinary monoprionidian Graptolites, so that his genus becomes synonymous with the section *Monoprionidae* as above defined. The grounds upon which this course is adopted are mainly the fact that a simple unicellular stipe is the unit out of which all these forms are built up, and the belief that the simple forms are very generally, if not universally, imperfect, and that they are to be regarded as mere fragments of complex forms. As regards the first of these grounds, it may be

urged that the monopronidian Graptolites differ from one another so greatly that the mere fact of their being essentially composed of a common elementary factor, or of similar factors combined in various ways, does not justify their being united in a single genus. On this ground, also, the dipronidian genera, *Diplograpsus* and *Climacograpsus*, should certainly be included in the same genus, since they do not differ from the monopronidian forms more than these latter do amongst themselves, and they have as their basis the same simple factor. This, indeed, was the course pursued by Hall in his great work on the Quebec Graptolites, but he seems now to have abandoned this view.—(Twentieth Report on the State Cabinet, p. 226.) As regards the second of these grounds, there can be no question as to the existence of a very large group of Graptolites consisting in their adult condition of *single* monopronidian stipes. This is now to some extent admitted by Hall himself, and it is abundantly confirmed by the occurrence of such forms in many deposits in Europe in which no complex Graptolites are known to exist at all. The mode of growth of these simple forms, and their absence of any bilateral symmetry in their development, constitute, in my opinion, ample grounds for their separation as a distinct genus, to which, in accordance with the practice of British palæontologists, I shall restrict the genus *Graptolites*.

Vertical Range.—With doubtful exceptions, no member of this genus is known to occur in the Skiddaw and Quebec Groups, or in the Lower Llandeilo Rocks. The genus is largely represented in the Upper Llandeilo Rocks, and seems to have attained its maximum in the Caradoc period. It passes onwards into Upper Silurian deposits, and is found in the Upper Ludlow Rocks. The genus *Graptolites* is, therefore, by no means one of the earliest representatives of the *Graptolitidæ*; but no other form except *Retiolites* endured so long, and is found in such late deposits.

II. GENUS DIDYMOGRAPSUS, M'Coy.—*Polypary bilaterally symmetrical, consisting of two simple monopronidian stipes springing from an "initial point," which is generally marked by a distinct "radicle" or spine (fig. 48).*

The genus *Didymograpsus* was originally proposed by M'Coy (1851) to include those Graptolites which are "bifid



Didymograpsus V-fractus, after
Salter. Skiddaw Slates.

from the base" (Palæozoic Fossils, p. 9). This definition has been very generally accepted by British palæontologists, but all the *Didymograpsi* are placed by Hall in his genus *Graptolithus*. The frond in *Didymo-*

grapsus consists of two simple monoprionidian stipes which diverge from a common point of union, where there is usually a longer or shorter mucro or "radicle." This marks the organic base of the polypary, but it is sometimes very much reduced in size, or may be altogether wanting. The cellules are variously placed in different species, usually occupying the side of the frond opposite to the radicle, but being sometimes placed on the same side as the radicle. The angle included between the two diverging stipes, *upon the side opposite to the radicle*, may be called the "angle of divergence," whilst the opposite angle, included between the stipes on the same side as the radicle, may be termed the "radicular angle."

The species of the genus *Didymograpsus* may be conveniently and naturally divided into three sections:—

1. Those *Didymograpsi* in which the radicle is on the inferior aspect of the frond, and the cellules are on the opposite or superior aspect, whilst the "angle of divergence" of the two stipes is not greater than 180° . This group comprises *D. Murchisoni*, *D. geminus*, *D. affinis*, *D. patulus*, and, in fact, the greater number of the *Didymograpsi* (fig. 48).

2. Those *Didymograpsi* in which the radicle is on the inferior side of the frond, and the cellules on the opposite or superior aspect, as before; but the angle of divergence of the stipes is now greater than 180° . In this group,* which differs

* Mr Hopkinson places the members of this group in a new genus under the name of *Dicellograpsus*, upon the ground that what I regard as the "radicle" is an ornamental spine. I shall, however, hereafter, produce ample evidence that the process which I regard as the radicle in these forms is truly of this nature. This view may introduce "confusion;" but the real question is simply whether it is correct, and on this point the materials in my hands permit of no reasonable doubt.

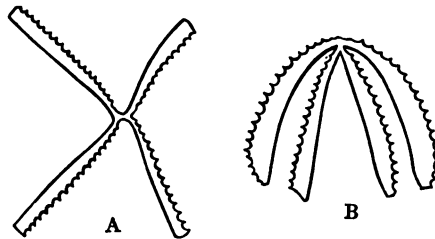
from the last only in the fact that the stipes are reflexed, are *D. flaccidus*, Hall, and *D. anceps*, Nich. (fig. 24, a, b).

3. Those *Didymograpsi* in which the radicle maintains its position, but the situation of the cellules is reversed, these being now placed on the inferior aspect of the frond, or on same side as the radicle. In this group are *D. sextans*, Hall, and *D. divaricatus*, Hall (figs. 31 and 30).

Vertical Range.—The genus *Didymograpsus* has both its commencement and its maximum in the rocks of the Skiddaw and Quebec Groups, in which it is represented by numerous and peculiar forms. It occurs also in the Lower Llandeilo, and is well represented in the Upper Llandeilo Rocks. In Britain the genus is hardly known to occur in the Caradoc period, but it has several representatives in rocks of this age in America. No *Didymograpsus* is known in the Upper Silurian, and the genus is to be regarded as essentially characteristic of the earlier portion of the Lower Silurian period.

III. GENUS TETRAGRAPSUS, Salter.—*Polypary bilaterally symmetrical, consisting of four simple monoprionidian stipes, arising from a central non-celluliferous connecting process, or "funicle," which bifurcates at both ends. The celluliferous branches do not subdivide, and a central corneous disc may or may not be present* (fig. 49).

Fig. 49.



A, *Tetragrapsus bryonoides*, Hall, sp. (After Hall.) B, Another individual of the same, showing the commoner form of the species. Enlarged from a specimen from the Skiddaw Slates. (Original.)

The genus *Tetragrapsus* was founded by Mr Salter (Quart. Journ. Geol. Soc., xix.) to include the four-stiped Graptolites, which resemble two *Didymograpsi* united by their bases, the

combined radicles forming a central non-celluliferous process or "funicle." In some species the four stipes are united at their bases by a central corneous disc (fig. 36), which is sometimes prolonged in wing-like extensions along the stipes (fig. 37). In the commoner species, however (figs. 32 and 49), a central disc has not been shown to exist, and is certainly wanting in all ordinary specimens.

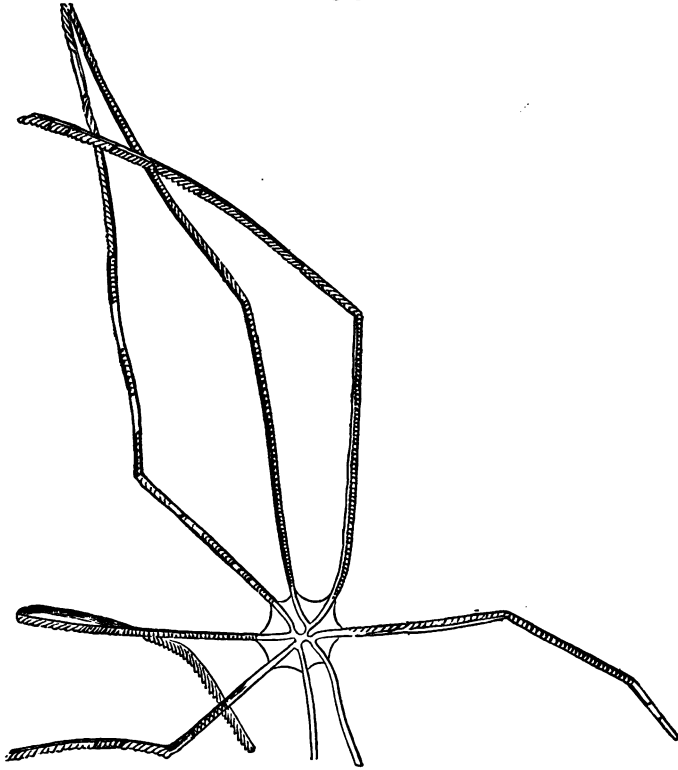
Vertical Range.—The genus *Tetragrapsus*, so far as is known, is entirely confined to the horizon of the Skiddaw and Quebec Rocks, being represented by identical species in both the north of England and Canada.

IV. GENUS *DICHOGRAPsus*, Salter.—*Polypary bilaterally symmetrical, consisting of eight or more simple stipes, united centrally at the base by a non-celluliferous "funicle," the divisions of which correspond in number with the stipes. The primary subdivisions of the funicle are always, and the secondary subdivisions generally, non-celluliferous. The stipes are monopronidian, and are given off from the funicle in a radiating manner. The divisions of the funicle are sometimes, but not always, enveloped in a corneous disc* (fig. 50).

The genus *Dichograpsus* was proposed by Mr Salter for certain complex Graptolites of the Skiddaw and Quebec Series, the essential part of the original definition being the possession of a "frond repeatedly dichotomous from a short basal stipe into eight, sixteen, twenty-four, or more branches, each with a single row of cells," the lower part of the stipes being enveloped in a corneous cup.—(Geologist, i. p. 74, and Quart. Journ. Geol. Soc., xix. p. 139). Professor Hall, however, showed that Mr Salter was in error when he made the dichotomous division, the even number of the branches, or the possession of a corneous disc, an essential element of the diagnosis, and he referred all the *Dichograpsi* to his genus *Graptolithus*. Still, the genus is a good one, and is certainly necessary, though Mr Salter's definition requires modification. In the 'Twentieth Report on the State Cabinet' (1868), Hall has broken up the forms included under *Dichograpsus* into three groups, which appear to be very natural, and which, I think, ought undoubtedly to be adopted. In the first of these

groups are the eight-stiped forms (fig. 50), in which a central disc is sometimes present, sometimes absent. Hall assigns no name to these, but they ought exclusively to form the genus *Dichograpsus*, which should not include any forms with more than eight stipes. *Dichograpsus* would thus include forms which might be regarded as composed of four *Didymo-*

Fig. 50.

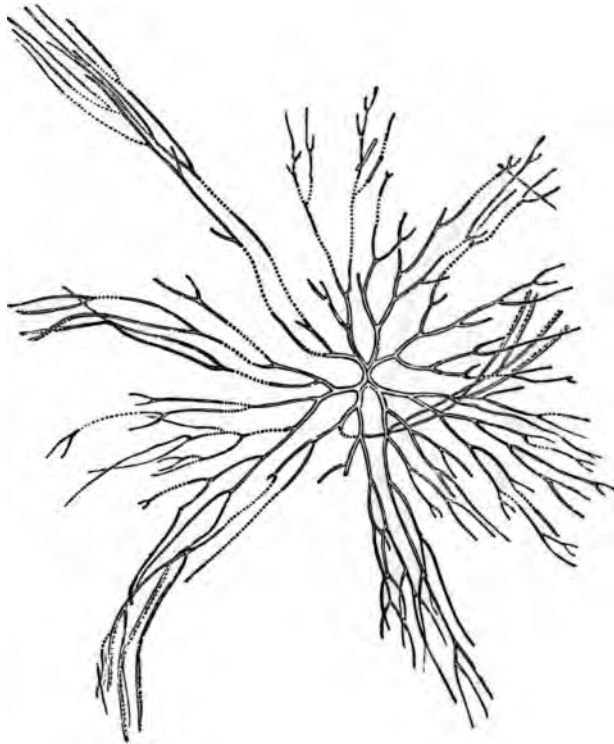


Dichograpsus octobrachiatus, Hall, sp. (After Hall.)

grapsi united by their bases. In the second group is only a single form, which Hall names *Loganograpsus*, and which I shall define immediately. In the third group are a number of forms for which Hall proposes no name, and which, therefore, I have temporarily left in the genus *Dichograpsus*, as above defined. These forms, however, should undoubtedly

be removed from *Dichograpsus*, and should be considered as forming a distinct genus, for which their distinguished discoverer will, I trust, propose a distinct title. These forms, such as *D. flexilis* (fig. 51), are distinguished from the true *Dichograpsi* by having a polypary composed of more than eight stipes "proceeding from a single axis, and more or less

Fig. 51.

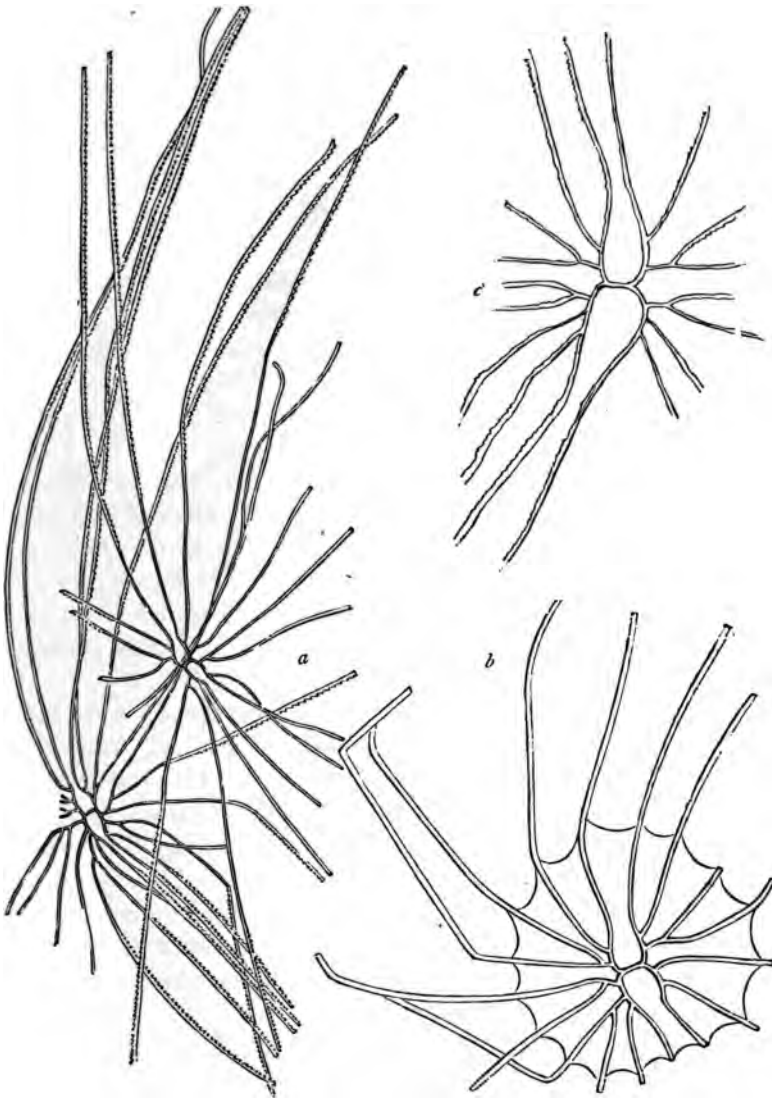


Dichograpsus flexilis, Hall, with a portion enlarged. (After Hall.)

frequently branched during their entire length." They are not known in any case to possess a central corneous disc.

Vertical Range.—The genus *Dichograpsus*, like *Tetragrapsus*, is exclusively confined to the horizon of the Skiddaw and Quebec Groups; and identical species occur in the north of England and in Canada.

Fig. 52.



Loganograpsus Logani, Hall. (After Hall.) The left-hand figures show two individuals, natural size. The lower right-hand figure is a magnified representation of the divisions of the funicle and the central disc. The upper right-hand figure represents the base of a specimen from the Skiddaw Slates, in which no disc is present.

V. GENUS LOGANOGRAPSUS, Hall.—*Polyptych composed of more than eight simple monopryonidian stipes (from 18 to 25), which arise from a central funicle, and give off no secondary branches. The divisions of the funicle are usually embraced by a broad corneous disc* (fig. 52).

In Hall's definition of this genus (Twentieth Annual Report on the State Cabinet, p. 226), the presence of a corneous disc is given as one of the peculiarities of the genus. Elsewhere, however, he states that a disc is not always present; and the only specimen in my possession, though well preserved, shows no traces of this appendage.

Vertical Range.—*Loganograpsus* is exclusively confined to the Skiddaw and Quebec Series. Only one species is known, and this occurs both in the north of England and in Canada.

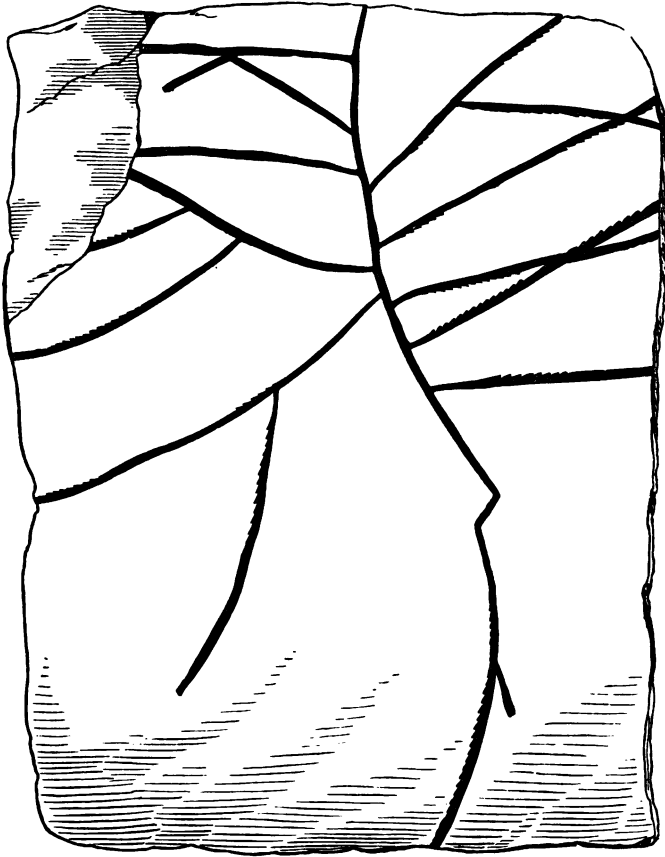
V. GENUS PLEUROGRAPSUS, Nich.—*Frond growing bilaterally from an initial point, which is usually marked by a long and slender radicle. The polyptych consisting of two primary stipes, which are celluliferous on one side, and which give off branches from both sides, the branches carrying cellules on one side, and giving off secondary branches in a similar manner* (fig. 53).

Only one species exists which can be referred with certainty to this genus—viz., *P. linearis*, Carr. sp., from the Upper Llandeilo Shales of Dumfriesshire. This remarkable Graptolite was originally described by Mr Carruthers under the name of *Cladograpsus linearis* (Ann. and Mag. Nat. Hist., iii., No. 13). This genus, however, had previously been established by Geinitz for certain of the *Didymograpsi* and *Dicranograpsi*, "zweiarmige oder gabelformige Graptolithinen;" and it should, therefore, be either retained in its original sense or altogether abandoned. In this opinion I am supported by the authority of Professor Hall (Twentieth Report of the State Cabinet, p. 235), and in this belief I proposed for this form the new generic title of *Pleurograpsus* (Geol. Mag., iv., June 1867).

The peculiarity of *Pleurograpsus*, by which it is distinguished from all the branching monopryonidian Graptolites which are

more complex than the *Didymograpsi*, is the absence of any non-celluliferous central portion or "funicle," from which the celluliferous branches spring. In *Pleurograpsus*, on the other

Fig. 53.



Pleurograpsus linearis, Carr., sp. Natural size. From a specimen from the Upper Llandeilo Shales of Dumfriesshire. (Original.) The central stipe in this specimen is not seen to bear cellules over its whole extent, but other specimens show this character conclusively.

hand, the two primary branches which spring from the radicle bear cellules immediately (fig. 54), and there is thus *no* basal

non-celluliferous "funicle." This point has not been fully recognised by Hall (*Op. cit. supra*, p. 235), who believes the primary stipes to be only celluliferous at their extremities, and thus to constitute a true funicle. On this ground he refers *Pleurograpsus* to his genus *Cænograpsus* (= *Helicograpsus*,

Fig. 54.



Base of *Pleurograpsus linearis*, showing the primary stipes, proceeding from the radicle, and bearing cellules. Enlarged. (Original.)

Nich.) Another point not recognised by Hall is the compound mode of branching. Not only do the primary stipes give off secondary branches from both sides (fig. 52), but these in turn give off lateral branches in a similar manner. The frond is, therefore, truly branched and *re-branched*. These two peculiarities, in my opinion, fully warrant our retaining *Pleurograpsus* as a distinct genus.

Vertical Range.—The genus *Pleurograpsus* is doubtfully represented in the Skiddaw Slates by a single form (*P. vagans*, Nich.) This, however, is known by a single incomplete specimen only, so that this determination may very possibly be incorrect. In this case the genus is as yet only known as occurring in the Upper Llandeilo Rocks of Dumfriesshire, in which it is represented by the single species *P. linearis*.

VII. GENUS CÆNOGRAPSUS, Hall (= HELICOGRAPUS, Nich.)—*Frond bilaterally symmetrical, composed of a non-celluliferous stem or "funicle," which is curved into the shape of the letter S., and gives off simple monopronidian stipes from the two convex portions of the curve, so that they form two distinct sets, diverging in different directions. The extremities of the funicle, where the branches cease to be given off, become themselves also celluliferous on one side; and in the centre of the funicle a small radicle may occasionally be detected. The celluliferous branches are not known to subdivide.* (Fig. 55.)

Only one species of this genus is known, and it was orig-

inally described by Hall from the Shales of the Hudson River Group, under the name of *Graptolithus gracilis* (Pal. N. York, i. p. 274). The first English specimens were discovered by Professor Harkness, and were described by him under the name of *Rastrites Bar- randi* (Quart. Journ. Geol. Soc., xi. p. 475). Subsequently it was placed by Mr Carruthers in his genus *Cladograpsus* (Geol. Mag., v. p. 130). In 1868 I described it as the type of a new genus, for which I proposed the name of *Helicograpsus* (Ann. and Mag. of Nat. Hist., July 1868); and in the same year Professor Hall recognised its generic distinctness, and proposed for it the name of *Cænograpsus* (Twentieth Report of the State Cabinet, 1868). I have only recently become aware that this name had been proposed by Hall; and as he was the original discoverer of the species, I willingly abandon my genus in favour of his.



Fig. 55.

Cænograpsus (*Helicograpsus*)
gracilis, Hall. Restored.
(Original.)

Cænograpsus is distinguished from *Pleurograpsus* by the possession of a remarkably long and distinct "funicle," by the regular and definite plan upon which the branches are given off, and the absence of secondary offsets. It is probable that the perfect polypary was composed of two such fronds as above described and figured, placed transversely across each other in a cruciform manner; and though none of our English specimens would support this view, such a specimen has, according to Hall, been discovered in America (Grapt. Quebec Group, p. 14, note).

Vertical Range.—In Britain the occurrence of *Cænograpsus gracilis* has been determined in the Caradoc Formation of Ireland, but it does not occur in the Caradoc of the north of England. It is, however, tolerably abundant in parts of the Upper Llandeilo Shales of the south of Scotland. In America it occurs in the Hudson River Group (Caradoc).

VIII. GENUS CYRTOGRAPSUS, Carr.—"Polypary growing

in one direction from the proximal end, and giving off simple or compound branches at irregular intervals."—(Carruthers, Geol. Mag., v. p. 128.)

Fig. 56.



Portion of *Cyrtograpsus Murchisoni*, Carr. (After Carruthers.)

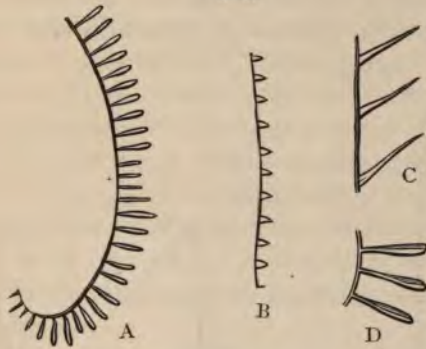
Having never met with any example of this genus, I can add nothing to the above definition by its discoverer, Mr Carruthers. I reproduce, however, a portion of the figure given by Mr Carruthers, of *Cyrtograpsus Murchisoni*, Carr., which is found in the Wenlock Rocks of Wales. Another doubtful form (*C. hamatus*, Baily) has been described from the Caradoc Rocks of Ireland.

IX. GENUS RASTRITES, Barrande.—*Frond consisting of a linear unbranched axial tube, giving rise on one side to a series of linear tubular cellules, which are directed at right angles to the stem, are free throughout their entire length, and are separated by distinct non-celluliferous portions of the polypary* (fig. 57).

The genus *Rastrites* is one of the most distinctly circumscribed in the entire group of the *Graptolitidæ*, and little need be added to the above definition. The separation of the cellules by distinct internodes, and their rectangular position as regards the common canal, sufficiently distinguish *Rastrites* from the genus *Graptolites*, to which it is otherwise nearly

allied. The nature of the base is not certainly known ; but as all the more perfect specimens curve upwards towards the proximal end, whilst the cellules diminish in size, we may conclude that the base resembles that of *Graptolites sagittarius*, His. (fig. 6). I have never been able to satisfy myself that a genuine "solid axis" is present in *Rastrites* ; but the axial tube often exhibits a longitudinal impressed line, which is probably due to compression, since the cellules present commonly the same appearance.

Fig. 57.



Morphology of *Rastrites*.—A, *R. peregrinus*, Barr. B, *R. capillaris*, Carr. C, *R. Linnæi*, Barr. D, Fragment of *R. peregrinus*, greatly enlarged. All enlarged. (Original.)

Vertical Range.—In Britain, so far as known, the genus *Rastrites* is exclusively confined to the Upper Llandeilo and Caradoc Rocks, and it occurs in the latter in America. In Bohemia, however, the genus is found in Etage E. at the base of the Upper Silurian Series.

SECTION B. DIPRIONIDÆ.

X. GENUS DIPLOGRAPTUS, M'Coy.—*Polyptych composed of two simple monoprionidian stipes, united back to back, their dorsal walls uniting to form a median septum, along the centre of which runs the solid axis. Cellules alternating with one another on the two sides of the frond, the cell-mouths being placed at the end of projecting "denticles." The base usually furnished*

with a "radicle," and the solid axis always (probably) prolonged beyond the distal extremity of the polypary (fig. 58).

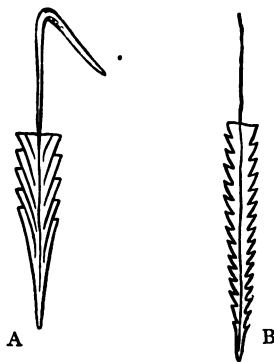
The genus *Diplograpsus* was originally founded by Professor M'Coy to include all the bicelluliferous Graptolites at that time known. It is an extremely natural genus, as above restricted, and I need add nothing to the above definition. The species of the genus are very numerous, and may be divided into three groups, according to the nature of the base. In the first of these groups are those *Diplograpsi* in which the base is furnished with three processes, a central "radicle," and two flanking spines springing from the bases of the first pair of cells (fig. 58). As a rule, all these processes are

Fig. 58.



Diplograpsus pristis, His.
(Original.)

Fig. 59.



A, *Diplograpsus cometa*, Gein.
B, *D. acuminatus*. Enlarged.
(Original.)

short, but they sometimes attain a considerable length. In the second group are those *Diplograpsi* such as *D. cometa*, Gein., and *D. acuminatus*, Nich. (fig. 59), in which there is no "radicle," in the ordinary acceptance of this term, but the two first cells are greatly elongated, and form with the solid axis a longer or shorter tapering basal process. In the third group are forms such as *D. pristiniiformis*, Hall, and

some examples of *D. tamariscus*, Nich., in which there is a basal extension of the solid axis, sometimes to a great length, beyond the proximal end of the polypary, but this is not flanked by lateral spines.

Vertical Range.—In Britain the genus *Diplograpsus* commences in the Skiddaw Slates, and continues to be represented through the Lower Llandeilo, Upper Llandeilo, and Caradoc Rocks, not being known above this point. In America the genus commences in the Quebec Group, and continues to the close of the Hudson River Group (Caradoc). In Britain and America, therefore, the genus *Diplograpsus* is exclusively Lower Silurian. In Bohemia, however, *Diplograpsi* are found at the base of Upper Silurian Rocks (Etage E. of Barrande).

XI. GENUS CLIMACOGRAPSUS, Hall.—*Polypary composed of two simple monoprionidian stipes united back to back, their dorsal walls coalescing to form a median septum, in the centre of which runs the solid axis—the cellules so welded together that their mouths appear as if sunk below the general surface of the polypary. Solid axis always prolonged beyond the distal extremity of the frond, and usually beyond its proximal extremity as well.* (Fig. 8.)

Having fully discussed the structure of *Climacograpsus teretiusculus*, His., in speaking of the general morphology of Graptolites (p. 15), there only remains a single point which I need notice here. In all the specimens of which I have had the opportunity of observing the intimate structure, *Climacograpsus* entirely resembles *Diplograpsus*, except in the fact that the mouths of the cellules are not placed at the end of projecting "denticles." On the contrary, the cellules are so bent that their mouths appear to be sunk below the surface, or "excavated," looking like notches when viewed laterally, and like transverse fissures when viewed from the front. It is believed, however, by Hall, Carruthers, and Hopkinson, that the two halves of the frond in *Climacograpsus* are not separated by any vertical partition or septum, formed by the union of the dorsal walls of the two stipes which compose the polypary. It is believed, on the other hand, by these observers, that the common canal communicates "between

the two series of hydrothecæ." In the case of *C. typicalis*, Hall—a species not yet recorded as British—Hall seems to have proved satisfactorily that the cell-partitions are in the form of triangular plates, having their apices attached to the solid axis, and having "an unequally-arched or convex upper surface and a concave lower surface."

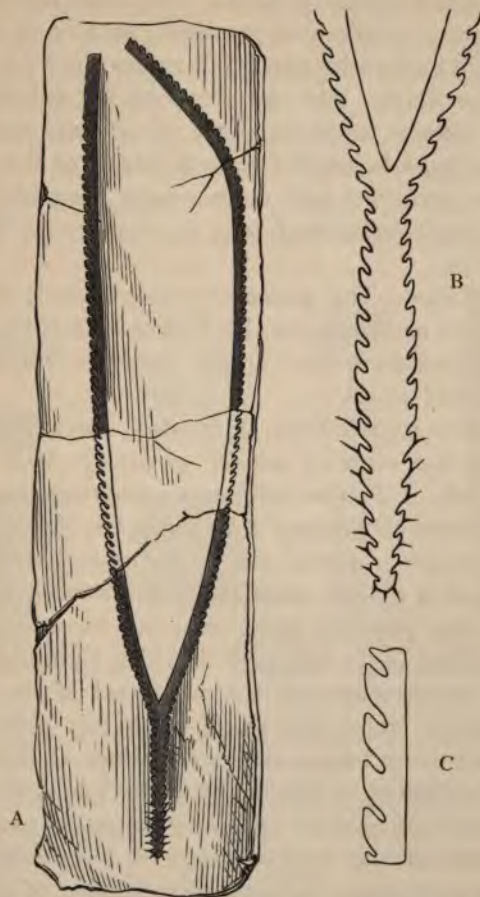
Still, this in no way proves the absence of a median septum, and there is nothing in Hall's description or figures which would render the presence of such a partition impossible. For my own part, having had the opportunity of examining a magnificent suite of specimens of *Climacograpsus teretiusculus*, His., preserved in *relief*, I can only say that in this species, as in all the other members of the genus which have come under my notice, there *is* a vertical septum dividing the frond into two independent halves, there is a distinct common canal to *each* half of the frond, and the cell-partitions do *not* reach the axis. If it should be proved that such a vertical septum is truly wanting in *C. typicalis*, Hall, a new genus must, I think, be established for its reception; for this is a point which would separate it from *C. teretiusculus*—the type-species—much more widely than this latter species is removed from *Diplograpsus*. In the meanwhile, however, whilst regretting to find myself opposed by such eminent authorities, I feel bound to maintain the accuracy of the views above expressed.

Vertical Range.—The genus *Climacograpsus* ranges in Britain from the Skiddaw Slates, through the Lower Llandeilo, Upper Llandeilo, and Caradoc Rocks, into the Lower Llandovery. In America it ranges from the Quebec Group to the Hudson River Group (Caradoc) inclusive. In Britain and America, therefore, the genus *Climacograpsus* does not pass above the limits of the Lower Silurian Rocks. It is impossible to doubt, however, that some of the specimens figured by Barrande (*eg.*, figs. 5 and 6, Pl. III., Grapt. de Bohême) are truly referable to *Climacograpsus teretiusculus*, His. In this case the genus extends its range in Bohemia into the base of the Upper Silurian Rocks (Etage E.)

XII. GENUS DICRANOGRAPSUS, Hall. — *Polypary* having

its proximal portion diprionidian, but dividing distally into two monoprionidian branches, which carry cellules on their outer aspect only. Cellules so welded together that their mouths appear as if sunk below the general surface of the polypary. Solid axis prolonged proximally as a minute radicle, flanked by two minute lateral spines (fig. 60).

Fig. 60.



A, *Dicranograpsus ramosus*, Hall, nat. size. B, Proximal portion of another specimen of the same, enlarged. C, Portion of one of the branches, enlarged. (Original.)

In its essential structure, the genus *Dicranograpsus* re-

sembles a *Diplograpsus*, or rather a *Climacograpsus*, the two component halves of which become separated distally, and diverge from one another at an approximately definite angle. This divergence of the two component elements of the frond, after a longer or shorter coalescence, is the only character which can be said to be of fundamental importance, and by this the genus is at once distinguished from the allied forms, *Diplograpsus* and *Climacograpsus*. The base resembles that of *Diplograpsus pristis* and its allies in having a minute central radicle flanked by two small spines derived from the first pair of cellules. The characters of the cellules, on the other hand, closely resemble those of *Climacograpsus*, their mouths being sunk below the general margin of the polypary. The cellules, however, still more nearly resemble those of certain of the *Didymograpsi* (e.g., *D. divaricatus*, Hall; and *D. anceps*, Nich.)

Vertical Range.—The genus *Dicranograpsus* is exclusively confined, as far as known, to the Upper Llandeilo period in Britain, but it occurs in the Caradoc Rocks of North America (Hudson River Group).

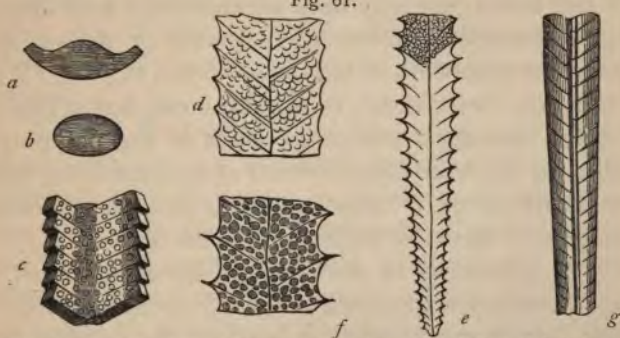
XIII. GENUS RETIOLITES, Barrande.—*Frond diprionidian, consisting of two rows of cellules, springing from a central cænosarcæal tube. A true solid axis sometimes wanting (?)*. Cellules in contact throughout their entire length. No distal or proximal extension of a solid axis, so far as known (fig. 61).

No genus is in a more unsatisfactory condition than *Retiolites*, Barr., and, pending more complete investigation, there are many points in its structure on which I am not prepared to offer any positive opinion. A great deal of the confusion and uncertainty which has arisen upon this subject seems to have been caused by a non-recognition of the immense differences presented by specimens of this genus according as they are preserved *in relief* or simply shown *in section*. This is shown even in the type-species, *R. Geinitzianus*, Barr.; though even in this case there are discrepancies of observation which cannot be explained in this way. According to Barrande and Geinitz, most of whose specimens appear to have been preserved in relief, the transverse section of the frond

of this species is somewhat triangular, the cell-apertures occupying the lateral angles of the triangle (fig. 61, *a*). On the contrary, I have obtained, from the Coniston Flags of the north of England a number of specimens of this form preserved in relief, which universally show a simple elliptical transverse section (fig. 61, *b*). I can offer no explanation of this discrepancy, but I am satisfied that my specimens are in every other respect identical with *R. Geinitzianus*, Barr.

A true solid axis, again, is not believed to exist by Barrande, who noticed the filiform median axis which is present in specimens preserved in section (fig. 61, *d*), but who believed this to be merely a portion of the external network or reticulation. Geinitz and Hall, however, believe that this is a true solid axis, and this is certainly the view to which I have been led by an examination of the specimens in my

Fig. 61.



Morphology of Retiolites. — *a*, Transverse section of *Retiolites Geinitzianus*, Barr., according to Barrande and Geinitz. *b*, Transverse section of the same in British specimens. *c*, Fragment of *R. Geinitzianus*, in relief (after Barrande), showing the lower surface. *d*, Fragment of *R. Geinitzianus* (?) in section, showing a solid axis, and the spinose projections of the cell-partitions. *e*, Another specimen of the same from the Coniston Mudstones, showing the axis, and the reticulation, which latter is omitted over the greater part of the figure. *f*, Fragment of *e*, greatly enlarged, showing the axis and reticulated fibres, the dark spaces being the surface of the shale seen through the network. *g*, *R. Geinitzianus* (?) from the Coniston Flags, split in half, and showing a coenosarc canal. All the figures are more or less enlarged, and all except *a* and *c* are original.

possession. This solid axis must, however, be placed excentrically as regards the axis of figure of the frond, and it is not shown at all in specimens preserved in relief. The axis of

figure of the polypary seems, on the other hand, to be occupied by a single central cœnosarcal canal, with which the two rows of cellules communicate by their bases. This central canal is sometimes left hollow, and can be well studied in specimens which are split in half (fig. 61, *g*). Upon the whole, then, it seems most probable that the two series of cellules in *Retiolites* are not separated by any continuous vertical septum (as in *Diplograpsus* and *Climacograpsus*), but that they spring from a common cœnosarcal tube, on one side of which is placed an excentric solid axis in the form of a single fibre.

Another great difficulty is presented by the reticulation or network of interlacing fibres, from which *Retiolites* derives its name. In specimens preserved in relief, this reticulation appears merely to be formed by a system of minute fibres which interlace and enclose small rounded or polygonal interspaces; and it has generally been regarded as a mere surface-marking. Specimens, however, preserved *in section*, show exactly the same network of interlacing fibres (fig. 61, *f*), and it thus becomes very difficult to avoid the conclusion that the entire space contained within the walls of the polypary is intersected by an interlacing system of anastomosing fibres. The nature, however, of this structure, becomes extremely problematical, if this view be founded upon fact.

Lastly, in specimens of *Retiolites* preserved in relief, the mouths of the cellules appear to be wholly unornamented. In specimens, however, preserved in section, the cell-partitions are seen to be prolonged beyond the general surface of the polypary in the form of projecting spines (fig. 61, *e, f*).

XIV. GENUS TRIGONOGRAPSUS, Nich.—*Frond simple, diprionidian, tapering towards the base, and having perfectly plain lateral margins which do not exhibit lateral denticles. Cell-partitions alternating with one another, and springing from an undulating or zig-zag solid axis. The solid axis excentric and placed on one side of a central cœnosarcal canal (?)* (fig. 62).

In the general shape of the frond, and in the fact that the cellules are in contact throughout their entire length, *Trigonograpsus* resembles *Retiolites*. To *R. venosus*, Hall, a further

point of resemblance is found in the presence of an undulating axis, to which the cell-partitions are attached. *Trigonograpsus*, however, differs from *Retiolites* in exhibiting no traces of reticulation or punctation. One specimen of *Trigonograpsus* in my possession shows very distinctly a central tube, which doubtless contained the coenosarc. In this case we must suppose the cell-partitions to be triangular in shape, and to be attached to the solid axis by their apices, and we must further suppose that the solid axis is excentric in position.

Vertical Range. — *Trigonograpsus* was founded by me to include a single form from the Skiddaw Slates of the north of England. If, however, the *Retiolites ensiformis* of Hall is, as I believe, referable in reality to this genus, then *Trigonograpsus* extended its range as far as Canada. No member of the genus, however, is known to have survived the period of the Skiddaw and Quebec formations.

XV. GENUS RETIOGRAPSUS, Hall.—“*Fronde simple? or compound, consisting of numerous simple stipes in bilateral arrangement, proceeding from an axis or radicle (or of simple stipes growing from their own radicles?) Stipes elongate-oval or lanceolate, with longitudinal axis and reticulate structure; margins ornamented with mucronate points. The axis often extends beyond the substance of the stipe in a mucronate tip, and in one species there are long setæ extending from what appears to be the base of the stipes.*” (Hall, Grapt. Quebec Group, p. 115.)

Having had no opportunity of examining any example of this genus, I have nothing to add to Hall's definition. The simple forms of the genus appear in many respects to resemble *Retiolites*, but the reticulate structure of the polypary is much less developed, and is, in fact, when present at all, confined to a series of marginal meshes; whilst the axis is well marked, and appears to be prolonged beyond both extremities of the frond. The compound forms (fig. 63) may be compared to a number of individuals of *Retiolites* united by a central non-

Fig. 62.

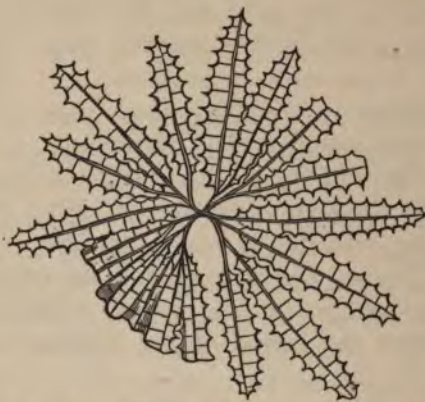


Trigonograpsus lanceolatus, Nich. Enlarged. (Original.)

celluliferous "funicle." I cannot, however, agree with Hall in thinking that the structure of these forms in any way supports the belief that the ordinary diprionidian forms may be merely fragments of similar composite organisms.

Vertical Range.—*Retiograpsus*, so far as known, is confined to the Quebec Group and to the Utica Slates (Caradoc).

Fig. 63.



Retiograpsus Eucharis, Hall, enlarged four diameters. (After Hall.)

SECTION C. TETRAPRIONIDÆ.

XVI. GENUS PHYLLOGRAPSPUS, Hall.—*Fronde foliiform, consisting of four simple monoprionidian stipes united back to back. The cellules in contact throughout their entire length, but furnished with strong projecting extensions from the lower lip of each cell-mouth (fig. 64).*

Phyllograpsus may be regarded as composed of two *Diplograpsi* placed at right angles with one another; or, more properly, as four simple monoprionidian stipes united back to back. On this view the "four slender flat laminae," regarded by Hall as the axis, should be looked upon as the dorsal walls of these component stipes. The presence of a true solid axis, in the form of a cylindrical rod, has never yet been satisfactorily demonstrated. The general form of the frond is ovate-lanceolate, thickest a little above the base, or in the

centre, and tapering to each extremity. A longer or shorter radicle is sometimes present.

In the commonest mode in which the *Phyllograpsi* present themselves, we have a view exhibiting the lateral aspect of two of the stipes, between the bases of which are shown the cell-mouths of a third stipe as transverse fissures, whilst the fourth stipe is imbedded in the stone below, and is invisible. I cannot do better, however, as concerns this point, than reproduce Hall's explanatory figure and description of the mode of preservation amongst the *Phyllograpsi* :—

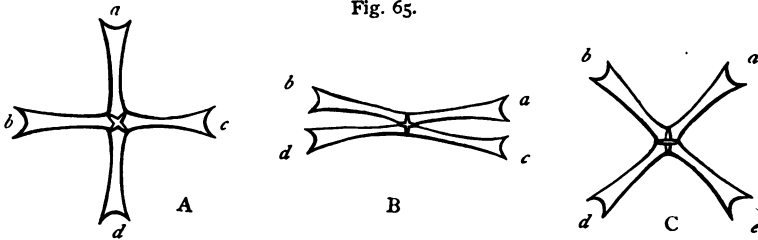
“When bodies of this kind were thrown down upon a muddy sea-bottom, they would become imbedded mainly in two positions. The most common position appears to be that in which the parts retain a vertical and horizontal direction, as in fig. 1” (see below); “the lower division or folium *d* would thus become first imbedded, while the folia *b*, *c* would lie in the plane of deposition, and *a* would be the last imbedded. The slaty laminæ

Fig. 64.



Group of individuals of *Phyllograpsus typus*, Hall. (After Hall.)

Fig. 65.



Diagrams to illustrate the mode of preservation of *Phyllograpsus*. (After Hall.)

separate along the line *b*, *c*, either above or below the folia *b*, *c*; leaving on one side the folia and on the other their impression. If the

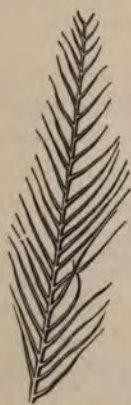
separation takes place above, then the bases of the cellules of *a* remain; these are directed obliquely downwards towards the base of the stipe. If the separation takes place below the folia *b*, *c*, the cellules of folium *d* are seen directed upwards, or towards the apex of the stipe. . . . The other direction of imbedding would be when the specimens were so deposited that the laminæ rested obliquely to the plane of stratification, as in fig. 3. In this way, from the accumulation of the sediment, they would become compressed, as in fig. 2, until the parts *b*, *d* and *a*, *c* would approach each other or come in contact."—(Grapt. Quebec Group, p. 118.)

Vertical Range.—The genus *Phyllograpsus*, so far as known, is exclusively confined to the Quebec Group of Canada and the Skiddaw Slates of the north of England—being represented in both formations by identical species.

SECTION D. DENDROIDEA.

XVII. GENUS PTILOGRAPSUS, Hall.—"*Frond plant-like, rooted? simple or branching. Branches and branchlets plumose, the pinnules rising alternately on opposite sides of the branches; celluliferous on one face only; branches cylindrical or flattened.*

Fig. 66.



A branch of *Ptilograpsus plumosus*,
Hall. Enlarged.
(After Hall.)

Substance corneous, dense; apparently smooth exteriorly, or corrugated by compression, or during fossilisation."—(Hall, Grapt. Quebec Group, p. 139.)

Ptilograpsus is singularly plant-like, and presents a very remarkable resemblance to some of the living *Plumulariæ*, such as *P. pinnata*, *P. setacea*, and *P. (Aglaophenia) pluma*. It seems certain, also, that no solid axis is present in *Ptilograpsus*, this constituting a striking structural difference as compared with the typical Graptolites. In the absence, however, of any proof that the organism is fixed, it were premature to refer *Ptilograpsus* definitely to the *Sertularida*.

Vertical Range.—In America, the genus *Ptilograpsus* is only known as occurring in the Quebec Group. In Britain it is not known in the corresponding formation of the Skiddaw

Slates; but I have described a well-marked species from the Lower Ludlow Rocks of Shropshire.

XVIII. GENUS DENDROGRAPSUS, Hall.—“*Fronds simple or aggregate, consisting of a strong footstalk, which is sometimes furnished below with a distinct root or root-like bulb, and above is variously ramified, and subdivided into numerous branches and branchlets, which are but slightly divergent; the whole producing a broad spreading shrub-like frond (fronds sometimes flabellate?) Branches celluliferous on one side; cellules appearing sometimes as simple indentations on the surface, and sometimes distinctly angular, with the denticles conspicuous. . . . Substance of the stipe and branches corneous, solid or tubular: surface striated.*”—(Grapt. Quebec Group, p. 126.) (Fig. 67.)

Fig. 67.



Dendrograpsus Hallianus, Prout. (After Hall.) *a*, A portion of the frond, of the natural size. *b*, An enlargement of one of the branchlets, showing the cellules. *c*, The main stipe and some of the principal branchlets, natural size.

Dendrograpsus is exceedingly plant-like in form, and agrees with *Ptilograpsus* in its general texture, and in apparently wanting any true solid axis. Its mode of branching is more nearly dichotomous than in *Ptilograpsus*, and it does not exhibit the lateral pinnæ, springing alternately from a main

branch, which characterise the latter genus. Its possession of a strong footstalk renders it almost certain that *Dendrograpsus* was fixed; though it has never been found actually attached to any solid body.

Vertical Range.—In America, *Dendrograpsus* ranges from the Potsdam Sandstone into the Quebec Group. In Britain the genus is only doubtfully represented in the Skiddaw Slates, but is known to occur in the Lower Llandeilo Rocks, and has also been indicated as occurring in the Caradoc Rocks of Ireland.

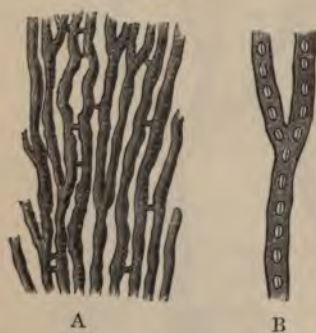
XIX. GENUS CALLOGRAPSUS, Hall.—“*Flabellate fronds, with numerous slender bifurcating branches proceeding from a strong stem or axis. Branches and divisions celluliferous on one side, the opposite side striate; sometimes distantly and irregularly united by transverse dissepiments.*” (Hall, Grapt. Quebec Group, p. 133.) (Fig. 68.)

Callograpsus is nearly allied to *Dendrograpsus*, but upon the

whole may with propriety be considered as intermediate between that genus and *Dictyonema*. The mode of branching differs a good deal from that of *Dendrograpsus*, the branches diverging less, and running nearly parallel with one another. The occasional presence, also, of transverse partitions, is a character by which *Callograpsus* nearly approaches *Dictyonema*.

As in the two preceding genera, there is the greatest probability that the frond was fixed by its proximal extremity, though this

Fig. 68.



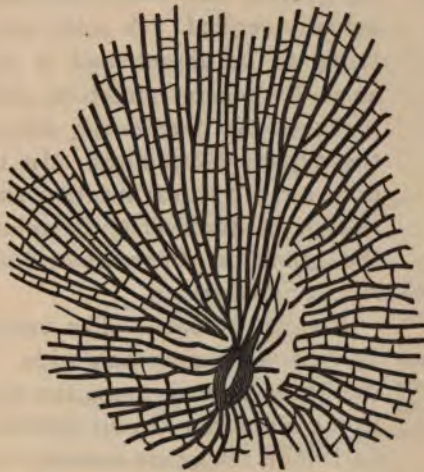
A, Portion of *Callograpsus Salteri*, enlarged. B, A branchlet of the same still further enlarged to show the cellules. (After Hall.)

has not yet been certainly shown.

Vertical Range.—*Callograpsus* is as yet only known with certainty to occur in the Quebec Group of Canada, but a species of this genus has been said to occur in the Caradoc Rocks of Ireland.

XX. GENUS *DICTYONEMA*.—*Fronds flabelliform, funnel-shaped, or conical, sometimes arranged in groups, composed of radiating branches, which frequently divide, but run nearly parallel with one another. All the branches are united together by delicate transverse bars or dissepiments. Cellules forming distinctly angular denticles, arranged on the sides of the branches in an alternating manner. Frond rooted? Substance corneous.* (Fig. 69.)

Fig. 69.



Dictyonema retiformis, Hall. (After Hall.)

In general appearance the *Dictyonemæ* very closely resemble the Polyzoan *Fenestellæ*. They differ, however, in being corneous in texture, and in having cup-shaped cellules which communicate with a common canal. The exterior of the branches are, according to Hall, strongly striated—a character which is also possessed by *Fenestella*. The cellules of *Dictyonema* are usually very conspicuous, and, when well preserved, present themselves as projecting angular denticles arranged in an alternating series on both sides of the branches (fig. 70). The branches usually subdivide more or less frequently as we recede from the base, but they run pretty nearly parallel to one another, so that the frond widens out only slowly, and a

more or less conical shape is usually attained. The mouths of the cellules, in some species at any rate, are provided with delicate spines, by which some at least of the transverse dissepiments are constituted. The branches, lastly, are everywhere united by numerous delicate transverse bars, the position of which is very irregular, though they often seem to rise from the cell-mouths.

Fig. 70.



Fragment of *Dictyonema socialis*, Salt. Considerably enlarged to show the cellules and transverse dissepiments. (Original.)

The frond in *Dictyonema* was almost certainly rooted, though, as in the three preceding genera, this conjecture has never been actually verified. A solid axis seems certainly to be absent, and in this character, as in its general structure, *Dictyonema* approaches the *Sertularida*, and recedes from the typical Graptolites. In the presence, however, of vertical striation, and in the possession of transverse dissepiments uniting the branches, *Dictyonema* differs from all recent Sertularians.

Vertical Range.—The vertical range of *Dictyonema* is extremely wide. In America the genus extends from the Quebec Group to the Hamilton Group (Middle Devonian). In Britain the genus extends from the Tremadoc Slates (Upper Cambrian?) to the Bala Limestone, and a species, apparently referable to this genus, has been found, above the latter formation, in the Gala Group of the south of Scotland.

SECTION E. INCERTÆ SEDIS.

XXI. GENUS THAMNOGRAPSUS, Hall. — "*Fronde consisting of straight or flexuous stipes (growing singly, or conjoined in groups at the base?), with alternating or widely-diverging branches; branches long, simple, or ramose in the same manner as the stipe. Substance fibrous or striate; the main stipe and branches marked by a central longitudinal, depressed line, indicating the axis. Cellules or serratures unknown.*" — (Hall, Grapt. Quebec Group, p. 141, fig. 71.)

The texture and substance of *Thamnograpsus* are the same as those of the true Graptolites, and it occurs in the same beds. In the absence, however, of any proofs of the existence of "hydrothecæ," it is impossible to speak positively as to the affinities of *Thamnograpsus*.

Vertical Range.—This genus is only known, as yet, as occurring in the Quebec Group of Canada, and in the Hudson River Group (Caradoc) of the State of New York.

Fig. 71.



Thamnograpsus typus, Hall. (After Hall.)

XXII. GENUS BUTHOGRAPSUS, Hall.—*Frond consisting of a central flexible stem or "rachis," giving origin to numerous short, flat, and simple pinnulæ, arranged in an alternating series on the two sides of the stem. No cellules have hitherto been discovered.* (Fig. 72.)

Vertical Range.—*Buthograpsus* is at present only known as occurring in the Trenton Limestone (Llandeilo-Caradoc) of the United States.

XXIII. GENUS INOCAULIS, Hall. — *Frond composed of flattened, corneous, or scabrous bifurcating stems, having a*

fibrous or plumose structure. (Hall, Pal. N. York, ii. p. 176.) (Fig. 73.)

Vertical Range.—The stems of *Inocaulis* have as yet only been found in the Shales of the Niagara Group (Wenlock) of the United States, associated with *Dictyonema*.

XXIV. GENUS CORYNOIDES, Nich.—*Polypary composed of a simple corneous tube, tapering slightly towards the base, where it is furnished with two small mucros or radicles, and expanding*

Fig. 72.



Buthograpsus laxus, Hall. Enlarged.
(After Hall.)

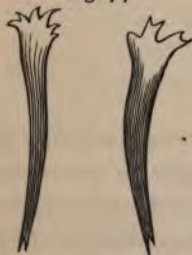
Fig. 73.



Inocaulis plumulosa, Hall.
(After Hall.)

distally into a sort of cup or calyx, the edges of which are divided into four or five equal or unequal teeth. No solid axis appears to be present, but the surface is sometimes longitudinally striated. (Fig. 74.)

Fig. 74.



Corynoides calicularis,
Nich. Enlarged.
(Original.)

The genus *Corynoides* was proposed by myself for a singular fossil, great numbers of which occur in parts of the Upper Llandeilo Shales of Dumfriesshire (Geol. Mag., iv., March 1867). These curious organisms, which I described under the name of *Corynoides calicularis*, occur amongst the Graptolites, and in the same state of preservation—viz., as flattened pyritous impressions, evidently of a corneous texture. The polypary varies in length from $\frac{1}{3}$ to $\frac{1}{2}$ an inch, and in perfect specimens the base is furnished with two small diverging spines. The lateral margins of the polypary are plain, but its distal end is expanded into a sort of cup, the edges of which are irre-

gularly toothed. No solid axis is to be detected, but there is occasionally longitudinal striation.

Corynoides appears to have consisted of a single polypite enclosed in a corneous tube, and it thus differs essentially from all the Graptolites. Its affinities would seem to be closest with the *Corynida*, some of which consist of a single polypite. We cannot, however, refer *Corynoides* to this order, since no living Corynid is free, as the former appears to have undoubtedly been. In the meanwhile, therefore, the systematic place of *Corynoides* must remain uncertain, though it clearly has certain relationships with the typical Graptolites. Under any circumstances, it shows no affinities with the *Palæocoryne* described by Professor Martin Duncan and Mr H. M. Jenkins as a Carboniferous genus of the *Corynida*.

Vertical Range.—*Corynoides*, so far as at present known, is exclusively confined to the Graptolitic Shales of Dumfriesshire of the age of the Upper Llandeilo Rocks.

END OF PART I.



